DOCUMENT RESUME

ED 148 820 95 SP 012 116

AUTHOR Klausmeier, Herbert J.; And Others
TITLE Second-Year Intervention Study to Facilitate Children's Concept Learning. Technical Report No. 429.
INSTITUTION Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
PUB DATE Dec 76
CONTRACT NE-C-00-3-0065
NOTE 103p.; For related document, see SP 012 119

EDRS PRICE MF-$0.83 HC-$6.01 Plus Postage.
DESCRIPTORS *Comparative Analysis; *Concept Formation; Educational Research; *Elementary Education; Individualized Instruction; *Instructional Design; Process Education; *Science Instruction
IDENTIFIERS *Concept Learning

ABSTRACT

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Technical Report No. 429

SECOND-YEAR INTERVENTION STUDY TO FACILITATE CHILDREN'S CONCEPT LEARNING

by

Herbert J. Klausmeier, Thomas S. Sipple, James E. Swanson,
and Joan M. Schilling

Report from the Project on
Conditions of School Learning and Instructional Strategies

Herbert J. Klausmeier
Faculty Associate

SP 012 116

Wisconsin Research and Development
Center for Cognitive Learning
The University of Wisconsin
Madison, Wisconsin

December 1976

Reprinted December 1977

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Center Contract No. NE-C-00-3-0065

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- providing assistance to educators which helps transfer the outcomes of research and development to improved practice in local schools and teacher education institutions

The Wisconsin Research and Development Center is supported with funds from the National Institute of Education and the University of Wisconsin.

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ACKNOWLEDGEMENTS

The authors wish to acknowledge the cooperation and assistance provided by F. R. Holt, Superintendent of Schools; L. Loofboro, Director of Elementary Education; H. Haag, Science Coordinator; and the staffs and school children of the participating elementary schools of the Janesville, Wisconsin, Public School System.

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ABSTRACT

Theory and research regarding levels of concept attainment and uses of concepts as specified by the conceptual learning and development (CLD) model are briefly described. The purpose and strategy of a longitudinal intervention study are detailed. This intervention study is designed (1) to determine the effects of specially prepared lessons on students' learning of key process-concepts of science, (2) to determine the effects of instructional programming for the individual student on achievement of the science content of a published science program (Science: A Process Approach [SAPA]), and (3) to determine the effects of the combined intervention treatments on students' attitudes toward their science instruction. Procedures for analyzing the process-concepts are given as well as for developing the process-concept lessons. Results obtained in the second year of the study are reported for each of the dependent measures. In general, the mean gain scores of the experimental schools were significantly higher than those for control schools on tests of the specific content of the SAPA curriculum. Results also showed scores on assessments of the science process-concepts to be generally higher for the treatment group in comparison with the control. In addition, results of a science attitude inventory are reported. Finally, plans for continuing use of process-concept lessons and for more fully differentiated instruction during successive semesters of the study are discussed.

I

INTRODUCTION

A substantial amount of research on concept learning has been completed during the past two decades dealing with the internal and the external conditions of concept learning. Content analyses of concepts and behavioral analyses of concept learning related to various subject-matter fields have also been conducted. Sufficient knowledge has accrued so that Klausmeier, Ghatala, and Frayer (1974) were able to formulate an analytic, descriptive model that specifies and describes the cognitive operations involved in the attainment of concepts at four levels of mastery by individuals whose abilities change in predictable ways with age. (We use "age" as a shorthand term to indicate the product of learning and maturation; age, per se, is not considered a determining factor of how well individuals can perform.) Five major propositions of the model are presented as a framework for clarifying part of the substantive basis of this longitudinal intervention study.

First, children learn four successively higher levels of the same concepts in an invariant sequence. The four levels are designated concrete, identity, classificatory, and formal. Attaining a concept at the concrete level is inferred when the individual recognizes an object that has been encountered on a prior occasion. Attainment of a concept at the identity level is inferred when the individual recognizes an object as the same one previously encountered when the object is observed from a different spatiotemporal perspective or sensed in a different modality, such as hearing or seeing. The lowest level of attaining a concept at

the classificatory level is inferred when the individual responds to at least two different examples of the same class of objects, events, or actions as equivalent. Individuals are still at the classificatory level when they can correctly classify a large number of instances as examples and others as nonexamples but they cannot define the word that represents the concept and also cannot explain the basis of their classifying in terms of the defining attributes of the concept. Attainment of a concept at the formal level is inferred when the individual can give the name of the concept, can define the concept in terms of its defining attributes, can discriminate and name its defining attributes, and can evaluate actual or verbally described examples and nonexamples of the particular concept in terms of the presence or absence of the defining attributes. The rates at which individuals attain the successive levels vary, and not all individuals attain the formal level of many concepts.

The second proposition is that certain mental operations are prerequisite for attaining each given level. One or more new operations are involved at each successively higher level. These new higher level operations are presumed to emerge as a product both of learning and biological maturation, or more broadly, of development. The attainment of any given concept at each successively higher level is explained, not as an additive reception process, but as a qualitatively different construction process.

Third, concepts when attained at the successively higher levels are used more effectively in understanding principles of which the concept is a part, in understanding taxonomic and hierarchical relationships of

which the concept is a part, and in solving problems involving the concept.

Fourth, having the name of given concepts and of their defining attributes facilitates the learning of the concepts at the concrete, identity, and classificatory levels and is essential for learning concepts at the formal level.

Fifth, the external conditions that facilitate attainment of each level differ according to the levels and are necessarily directed toward utilization of the operations essential for attaining the particular level (Klausmeier, 1976; Klausmeier, Ghatala, & Frayer, 1974).

The proposition that a concept is attained at the four successive levels applies only to those concepts that: (a) have more than one example, (b) have observable examples or representations of examples that are observable, and (c) are defined in terms of attributes. Not all concepts are of this kind. Some concepts have only one example, e.g., the earth's moon. Some do not have observable examples, e.g., atom, eternity, soul. Still others are defined in terms of a single dimension, e.g., rough, thin; or in terms of a relationship, e.g., south, between, above. Certain levels are, however, applicable to these kinds of concepts. For example, the identity level is applicable to concepts that have either one example or identical examples; the classificatory level is applicable to concepts of only one dimension or that express a relationship; and the formal level is to those concepts that have no observable, classifiable examples. The concepts used in the longitudinal intervention study necessarily meet the criteria as stated in (a), (b), and (c) above.

OVERVIEW OF THE LONGITUDINAL INTERVENTION STUDY

Purpose

The longitudinal intervention study is directed primarily toward clarifying the effects of certain external (instructional) conditions of concept learning. The purposes of the study are (1) to determine the effects of specially prepared lessons on students' learning of basic process-concepts of science, (2) to determine the combined effects of specially prepared lessons and of instructional programming for the individual student on students' achievement of outcomes related to a published science program (Science: A Process Approach [SAPA]), and (3) to determine the effects of the combined treatments on students' attitudes toward their science instruction. The intervention consists of two main procedures. First, printed lessons were developed that are intended to teach key process-concepts of science included in the SAPA program. These lessons were used to supplement the regular instruction. Second, the regular instructional procedure was modified from group instruction of heterogeneous groups to a beginning level of differentiated instruction that follows the model of instructional programming for the individual student. Here the strategy of the longitudinal study is to make minimum changes during the first year; and then, depending upon the results obtained, to move to more fully differentiated instruction during the successive semesters of the next school year.

Time Schedule

Table 1 provides a timetable for carrying out the intervention study and preparing the related reports. Two controlled experiments are scheduled for each school year from 1973-74 through 1977-78. During each of two years, 1974-75 and 1975-76, development of concept lessons for use by the children and evaluation instruments as needed to conduct the study was scheduled. The large effort in the development of tests was completed by the end of 1974-75 and of lessons by the end of 1975-76. Each year the detailed planning for the ensuing year is carried out with the staffs of the participating schools. Most of this is done in a workshop during the summer. In 1974-75, a tryout of some of the lessons was conducted. Implementation of the two intervention procedures for an entire school year was carried out during 1975-76, and the results are reported in this paper. The full-scale intervention is scheduled to continue into the 1976-77 school year with a final reporting of the entire study in 1978.

TABLE 1

TIMETABLE FOR INTERVENTION STUDY AND REPORTS

	1973-74	1974-75	1975-76	1976-77	1977-78	1978
Conducted controlled experiments	X	X	X	X	X	
Develop evaluation instruments and instructional materials		X	X			
Plan intervention procedures with school staffs		X	X	X		
Conduct trial intervention experiment		X				
Implement intervention process and gather data			X	X		
Deliver reports of research carried out prior year			X	X	X	X

Summary of Prior Results

During 1973-74 two controlled experiments were run to determine the extent to which children's level of concept attainment could be increased from the classificatory level to the formal level, as these levels are defined in the model of conceptual learning and development (Klausmeier, Ghatala, & Frayer, 1974). In one experiment (McMurray, Bernard, & Klausmeier, 1975) two experimental lessons to teach the concept equilateral triangle were developed and taught to fourth-grade children. In this experiment, a variation of the Solomon Four-Group design was employed to determine the effects of a pretest as well as the lessons. Performance of the participating 118 fourth-grade children indicated that experimental groups receiving the lessons performed better than did the control groups. A two month follow-up showed that the experimental groups receiving the lessons lost very little in performance and that the two control groups had increased their level of attainment only slightly. The pretest was found not to have a significant effect on performance. The specific results were: (1) 94 and 93 percent of the two experimental groups receiving the lesson attained the classificatory level, whereas 73 and 64 percent of two control groups did, and (2) 60 and 64 percent of the two experimental groups attained the formal level, whereas only 7 and 11 percent of the two control groups did. The performances of the fourth-grade experimental children is especially significant inasmuch as the performances of a comparable group of sixth-grade students attaining the classificatory level and the formal level of the same concept, equilateral triangle, were as follows: 90 percent attained

the classificatory level and 46 percent attained the formal level (Klausmeier, Sipple, & Allen, 1974b).

In another of the controlled experiments conducted during 1973-74, it was found that the materials designed to assess attainment of the concept tree were too easy for fifth-grade children. The study was therefore replicated with third-grade children in 1974-75 (Klausmeier, Schilling, & Feldman, 1976). The results of the 1974-75 study were similar to those of the McMurray, Bernard, and Klausmeier study (1975) involving equilateral triangle.

In both of the controlled studies carried out during 1973-74, the experimental lessons utilized methods which have previously been found to facilitate concept learning: presenting a definition of the concept together with rational sets of examples and nonexamples, emphasizing the defining attributes of the concept, teaching a strategy and providing immediate feedback. These same procedures and others were incorporated in lessons developed for the intervention study as is explained in Chapter 4.

Most of the 1974-75 school year was spent in developing and validating tests and lessons. However, in the early spring of 1975, an experiment was conducted to assess the effectiveness of a lesson the process-concept observing scientifically (Klausmeier, DiLuzio, & Brumet, 1976). Samples of students in the two experimental schools received the lesson observing scientifically, the related assessment, and a brief questionnaire to determine students' attitudes towards this type of lesson. Each teacher of grades 4 and 5 read the lesson and assessment aloud to the children

while grade 6 students read the lesson and assessment themselves. Members of the Project staff observed the conduct of the lesson and assessment at each grade level and noted few difficulties.

In both schools, some students received both the lesson and assessment (experimental) while other students received the assessment only (control). In school A teachers randomly selected students within classes who were to receive either the experimental or control treatment. Because of scheduling difficulties, students in school C were given either the experimental or control treatment as an entire class.

Differences in reading ability among the students were noted; therefore, the Vocabulary and Comprehension subtest scores of the Gates-MacGinite Reading Test were used as covariates for the analysis of covariance. The dependent variables for the analysis were the classificatory and formal subtest scores on the process-concept observing scientifically assessment. The data for those students who had scores on both covariates were included in the analysis.

The F-ratios for both classificatory and formal subtests were significant ($p < .001$) favoring the experimental group at school C. The F-ratios for both the classificatory and formal subtests were significant (classificatory with $p < .01$ and formal with $p < .001$), favoring the experimental students in school A. These results support the effectiveness of the process-concept lesson in increasing children's ability to classify instances of the concept observing scientifically as well as improving performance at the formal level.

Teachers were given a six-item questionnaire on the lesson and

assessment. All teachers felt the lesson met its objectives. Only one teacher felt that the lesson was too lengthy, and only one teacher felt the vocabulary was too difficult. In addition, students completed a four-item questionnaire on the lesson. Instructions and test questions were modified to eliminate problems cited by the teachers and the students.

DESIGN OF THE 1975-76 SECOND-YEAR INTERVENTION STUDY

Description of the Participating Schools

Two experimental and two control schools were selected for the intervention study by school district administrators. Each pair of experimental and control schools was selected so as to be matched as nearly as possible in socioeconomic, ethnic, and general demographic characteristics. Fifty to eighty percent of the populations of the four schools fall in the middle and higher-than-middle socioeconomic status. Blue collar, business, and professional occupational categories are represented by the parents of the children attending the schools. All four schools are implementing Individually Guided Education.

Participating Students

Two hundred sixteen children in their fifth year of schooling, corresponding to fourth grade in traditional schools, and 230 children in their sixth year, all the children who completed all the tests during the 1975-76 school year, were included in the data analysis. About seven percent of the children were absent from school late in the school year at the time of an outbreak of measles and were dropped when it became impractical to have them make up for the absences. The number of boys

and girls in each year was as follows: 123 boys and 93 girls in year five and 118 boys and 112 girls in year six. Separate analyses were not run for boys and girls inasmuch as sex differences had not been found in a descriptive longitudinal study (Klausmeier, Sipple, & Allen, 1974b; Klausmeier, Allen, Sipple, & White, 1976).

Intervention Process and Materials

As noted earlier, the specific plan for carrying out the intervention has two major elements. First, lessons developed by the Project staff were used by the teachers of the experimental schools. These lessons were designed to teach the "process" concepts of science that are incorporated in the published program Science: A Process Approach (SAPA). The concepts to be taught, therefore, deal with processes of science as defined in this published program: observing, classifying, inferring, predicting, measuring, using numbers, using space/time relationships, communicating, controlling variables, interpreting data, formulating hypotheses, defining operationally, and experimenting. Second, teachers changed their mode of instruction from one of keeping classroom groups intact to implementing instructional programming for the individual students (Klausmeier, 1977).

The general plans of the data collection and the intervention were as follows:

In both control and experimental schools, the 17 SAPA lessons were taught in the same sequence. Each teacher kept a descriptive log concerning the amount of time given to each lesson and the kinds of materials and activities used.

At the beginning of each semester in both the control and the experimental schools, the content-specific tests covering the SAPA lessons that were taught during the semester were administered as a pretest to all students enrolled at levels five and six (or fifth and sixth years of schooling). The same tests were administered at the end of each semester as a posttest.

In the experimental schools at each level, three groups of students were organized for instruction based on the pretest results: the top one-third, the middle one-third, and the bottom one-third in each school. In the control schools, the children were taught in heterogeneous, age-graded, classroom-size groups with some individualization. This was the manner in which teachers carried out their instruction before the study started.

In the experimental schools at the beginning of each process block (a set of SAPA lessons dealing with the same process), instruction was provided using a process-concept lesson developed by the Project. The process-concept lessons were not used in the control schools.

In the experimental schools, differences among the students in achievement on each process block of SAPA lessons and process-concept lessons as measured by posttests were to be provided for through enrichment activities for mastery group and reteaching for near-mastery group. However, time did not permit this except in minor amounts as is indicated later in this chapter in a summary of the logs kept by the teachers.

Data Collection

At the beginning of each semester, teachers in each of the experi-

mental and control schools administered those content-specific tests that correspond to the SAPA lessons being taught during that semester. The SAPA lessons for both level 5 and level 6 are given in Tables 2 and 3. At the end of the semester, after SAPA instruction, the tests were readministered. The lesson and testing sequence was the same for the four schools.

A short inventory, Attitude Towards Science, was administered to all experimental and control children at the beginning of the school year prior to any testing or instruction, again at the end of the first semester, and finally in the spring after all testing and instruction was completed.

In addition to the above testing, both the experimental schools receiving the process-concept lessons and the control schools not receiving the lessons were administered process-concept tests. The children in the control schools received these prior to the start of a SAPA process block of lessons while the children in the experimental schools received them also before the SAPA process block of lessons but after completing the process-concept lesson. The effects of the process-concept lesson were determined by comparing performances of the experimental and control students on the process-concept tests.

As noted earlier, in order to obtain explicit information concerning the implementation of the experimental materials and procedures in the experimental schools, a teacher's log was completed by all teachers for each SAPA lesson taught. The experimental school teachers recorded (1) the number of days and amount of time required to teach each SAPA lesson, (2) the number of students in each of three instructional groups

TABLE 2

TITLES AND SEQUENCE OF SAPA LESSONS TAUGHT AT LEVEL 5

	SAPA Lesson Title	SAPA Lesson Classification
First Semester	Rate of Change of Position	Using Space/Time 14
	The Color Wheel -- An Order Arrangement	Classifying 8
	Separating Materials from Mixtures	Classifying 9
	Observations and Inferences	Inferring 3
	Tracks and Traces	Inferring 4
	The Displacement of Water by Air	Inferring 5
	Surveying Opinion	Predicting 2
	Describing the Motion of a Bouncing Ball	Predicting 3
Second Semester	Dividing to Find Rates and Means	Using Numbers 10
	Metersticks, Money & Decimals	Using Numbers 11
	Temperature & Thermometers	Measuring 11
	Measuring Volumes	Measuring 12
	Describing the Motion of a Revolving Phonograph Record	Measuring 13
	Measuring Drop by Drop	Measuring 14
	Measuring Evaporation of Water	Measuring 15
	Observing Animal Responses to Stimuli	Observing 15
	Using Maps	Communicating 10

TABLE 3

TITLES AND SEQUENCE OF SAPA LESSONS TAUGHT AT LEVEL 6

	SAPA Lesson Title	SAPA Lesson Classification
First Semester	Describing and Representing Forces	Measuring 16
	Magnetic Poles	Observing 16
	Observing Growth from Seeds	Observing 17
	Observing Falling Objects	Observing 18
	Loss of Water from Plants	Inferring 6
	Inferring Connection Patterns in Electrical Circuits	Inferring 7
	Shape of Cut Things	Inferring 8
	2-D Representations of 3-D Figures	Using Space/Time 15
	Relative Position and Motion	Using Space/Time 16
Second Semester	Rolling Cylinders	Controlling Variables 1
	Upward Movement of Liquids	Controlling Variables 2
	Guinea Pigs in a Maze	Interpreting Data 1
	Observations and Hypotheses	Formulating Hypotheses 1
	Suffocating Candle	Predicting 4
	Using Punch Cards	Classifying 10
	Describing Location	Communicating 11
	Reporting an Investigation in Writing	Communicating 12

(high achievers, medium achievers, and low achievers), (3) how instruction was differentiated for each group, (4) the SAPA materials used, and (5) the supplementary materials used. The control school teachers recorded only (1), (4), and (5) from above.

The mean number of minutes spent by teachers in each school on each SAPA lesson block is presented in Tables 4 through 7. Although, in general, teachers in experimental schools reportedly spent more time on the SAPA lessons, this included the time used for administering the posttest which immediately followed instruction in the experimental schools. Little time was available for reteaching students who were near mastery or for providing enrichment activities for students who had achieved mastery of the SAPA lesson.

Data Analysis

The SAPA content-specific posttest scores were analyzed by semester and by the entire year using analysis of covariance with the pretest scores serving as the covariate. This analysis was done with each pair of experimental and control schools (E1 with C1 and E2 with C2) as well as with the combined experimental and combined control schools (E1 and E2 with C1 and C2). The scores attained on the Project developed process-concept tests were analyzed using analysis of variance. The posttest attitude inventory scores were analyzed using analysis of covariance, using the scores from the first administration of the attitude inventory as the covariate.

TABLE 4

MEAN NUMBER OF MINUTES SPENT ON SAPA LESSON
AND PROCESS-CONCEPT LESSON INSTRUCTION
AT LEVEL 5 DURING FIRST SEMESTER

	Experimental		Control	
Lesson	School E1	School E2	School C1	School C2
SAPA Classifying 8	137	150	115	150
SAPA Classifying 9	140	170	110	90
Classifying Process-Concept Lesson	150	150	0	0
SAPA Inferring 3	140	147	115	120
SAPA Inferring 4	140	150	120	120
SAPA Inferring 5	137	150	120	120
Inferring Process-Concept Lesson	150	120	0	0
SAPA Predicting 2	140	150	105	120
SAPA Predicting 3	140	160	105	135
Predicting Process-Concept Lesson	120	100	0	0

TABLE 5

MEAN NUMBER OF MINUTES SPENT ON SAPA LESSON
AND PROCESS-CONCEPT LESSON INSTRUCTION
AT LEVEL 5 DURING SECOND SEMESTER

	Experimental		Control	
Lesson	School E1	School E2	School C1	School C2
SAPA Using Numbers 10	150	150	130	150
SAPA Using Numbers 11	150	150	130	150
Using Numbers Process-Concept Lesson	150	150	0	0
SAPA Measuring 11	130	130	120	120
SAPA Measuring 12	150	150	140	120
SAPA Measuring 13	150	150	90	90
SAPA Measuring 14	150	150	160	180
SAPA Measuring 15	150	150	120	120
Measuring Process-Concept Lesson	150	150	0	0

TABLE 6

MEAN NUMBER OF MINUTES SPENT ON SAPA LESSON AND PROCESS-CONCEPT LESSON INSTRUCTION AT LEVEL 6 DURING FIRST SEMESTER

	Experimental		Control	
Lesson	School E1	School E2	School C1	School C2
SAPA Observing 16	180	150	120	135
SAPA Observing 17	220	150	135	135
SAPA Observing 18	120	150	120	180
Observing Process-Concept Lesson	180	150	0	0
SAPA Inferring 6	140	150	180	180
SAPA Inferring 7	360	185	135	180
SAPA Inferring 8	200	145	180	180
Inferring Process-Concept Lesson	120	120	0	0
SAPA Using Space/Time 15	160	150	120	120
SAPA Using Space/Time 16	60	90	60	180
Using Space/Time Process-Concept Lesson	120	135	0	0

TABLE 7

MEAN NUMBER OF MINUTES SPENT ON SAPA LESSON
AND PROCESS-CONCEPT LESSON INSTRUCTION
AT LEVEL 6 DURING SECOND SEMESTER

	Experimental		Control	
Lesson	School E1	School E2	School C1	School C2
SAPA Controlling Variables 1	180	240	150	135
SAPA Controlling Variables 2	180	240	150	180
Controlling Variables Process-Concept Lesson	180	200	0	0
SAPA Communicating 11	60	150	180	180
SAPA Communicating 12	40	150	150	135
Communicating Process-Concept Lesson	120	120	0	0

II

RATIONALE UNDERLYING THE INTERVENTION PROCEDURES

VARIABLES INCORPORATED IN THE PROCESS-CONCEPT LESSONS

According to the model of conceptual learning and development (Klausmeier, Ghatala, & Frayer, 1974), a concept becomes more useful to the individual as it is attained at successively higher levels. Concepts attained at the classificatory and formal levels can be used in identifying new examples and nonexamples of the concept, in understanding principles involving the concept, and in understanding taxonomic relationships involving the concept. It has also been found that having verbalizable concepts may facilitate problem-solving involving those concepts (Gagné & Dick, 1962; Wittrock, 1963). The role of the process-concept lessons in the present study is to teach the basic process-concepts of science and, thereby, to supplement the SAPA lessons by providing verbalizable concepts of these processes.

Several instructional variables have been proven effective in facilitating subject-matter concept learning. Printed instructional materials to teach concepts can be used effectively with students who can read and who have already attained the target concept at the beginning classificatory level. The materials may be used to aid students to classify more correctly and extensively at the classificatory level, to attain a beginning formal level, and to attain an adult formal level.

Sufficient knowledge has accrued from preceding studies (Bernard,

1975; Klausmeier, Schilling, & Feldman, 1976; McMurray, Bernard, & Klausmeier, 1975) and other studies to be reported that the instructional conditions which follow are regarded as fully validated. It is clear also that the conditions which follow can be incorporated in printed materials.

1. Establish an intention to learn concepts. An intention to learn concepts is developed before the student tries to learn a particular concept. This is done by telling the students that they will be learning concepts, by pointing out important features of concept learning, or by describing the concept population comprising the taxonomy or hierarchy. Amster (1966), Fredrick and Klausmeier (1968), Kalish (1966), Laughlin, Doherty, and Dunn (1968), and Osler and Weiss (1962) all reported facilitative effects from instructions designed to establish an intent to learn concepts. Ausubel (1968) has demonstrated the facilitative effects of advance organizers on learning various kinds of new materials and Bernard (1975) has shown the facilitative effects in connection with a taxonomy of concepts.

Establishing an intention to learn concepts (as opposed, for example, to establishing a set to memorize the individual instances) activates several operations essential to attaining concepts at the classificatory and formal levels. First, such instructions may alert the learners to attend to and discriminate the attributes of instances. Second, such instructions may engage the learners in an active search for the attributes which distinguish instances from nonin-

stances. At the outset, then, the learners are engaged actively in searching behaviors directed toward learning the particular concept or concepts to a higher level of attainment.

2. Elicit student verbalization of the concept name and the defining attributes. To accomplish this, a vocabulary list is presented at the beginning of a series of lessons, and the students are taught to recognize the words.

Having the concept and attribute labels greatly facilitates carrying out both inductive and deductive operations at the formal level of attainment, including formulating, remembering, and evaluating hypotheses and assimilating and processing information that is presented verbally in an expository approach to instruction. Linguistic codes are maximally efficient for carrying out the sequential information processing which is involved in inferring concepts from examples and nonexamples inductively, and also for assimilating the information as presented in a definition, a set of verbal examples and nonexamples of the concepts, and verbal explanations or descriptions. Clark (1971) reported facilitation of concept attainment through giving the label of the concept and/or the labels of its defining attributes. When printed material is used, the students must not only be able to use the terms orally, they must also be able to read them.

3. Emphasize the defining attributes of the concept by drawing the students' attention to them. Giving students the names of the defining attributes of the concept in the concept definition is insufficient for teaching them to discriminate the defining attributes and to use them

subsequently in differentiating examples from nonexamples of the concept. Frayer (1970) found that emphasizing the defining attributes by verbal cues improved immediate concept learning and later transfer and retention.

Merrill and Tennyson (1971) compared the effects of a concept definition, a definition of the attributes of the concept, a rational set of examples and nonexamples, and attribute prompting singly and in various combinations. Attribute prompting was found to be more facilitative than a definition of the concept or definitions of the attributes. The most effective condition included all four variables. Clark (1971) reported that a large majority of researchers found beneficial effects of directing the students' attention to the concept attributes and/or the conceptual rule; also, pointing out the attributes and rules to the students yielded better results than permitting the students to discover them themselves.

4. Present a definition of the concept in terms of defining attributes, stated in vocabulary appropriate to the target population. Providing students with the concept definition eliminates the operations involved in identifying the defining attributes of the concept and inferring the concept from experiences with examples and nonexamples of the concept. However, simply presenting students with the concept definition does not insure concept attainment -- the students may merely acquire a rotely memorized string of verbal associations. To insure that the students acquire a concept and not a string of words, at a minimum, they must also be presented with concept examples and nonexamples to classify. Correct classification requires that the students differentiate examples from

nonexamples on the basis of the defining attributes contained in the concept definition. Thus, both discriminating the attributes of instances and evaluating instances to determine whether or not they exhibit the defining attributes contained in the definition are operations involved after the student is given the concept definition.

The facilitative effect of a definition varies as a function of several variables including the number of rational sets of examples and nonexamples presented. In a controlled experiment with fourth-grade students Klausmeier and Feldman (1975) found a definition to have about the same amount of facilitation as one rational set of examples and nonexamples. A definition combined with one rational set was more effective than a definition or a rational set alone; and a definition combined with three rational sets showed greatest facilitation.

A definition must be stated in appropriate terminology. Feldman and Klausmeier (1974) found a common usage definition to be more effective than technically stated definition with fourth-graders; whereas the technically-stated definition was more effective with eighth-graders. Feldman (1972) and Merrill and Tennyson (1971) also reported a facilitative effect for definitions.

5. Provide a strategy for differentiating examples and nonexamples. Bruner, Goodnow, and Austin (1956) described various reception and selection strategies that students learn incidentally, without instruction concerning the strategies. Fredrick and Klausmeier (1968) and Klausmeier and Meinke (1968) reported the facilitative effects of teaching students strategies for attaining concepts. Bernard (1975), McMurray, Bernard,

and Klausmeier (1975), and Klausmeier, Schilling, and Feldman (1976), incorporated the same strategy for evaluating instances as examples or nonexamples in their experimental lessons with excellent results. Teaching the efficient strategy in the printed material ensures that an effective strategy will be learned and eliminates much trial-and-error learning. Providing for the students to use the strategy in identifying examples and nonexamples and providing feedback promotes active learning of the strategy. In this connection, students of low socioeconomic status do not learn mature conceptualizing skills related to certain subject matters unless they receive appropriate instruction during the school years in those subject matters (Nelson & Klausmeier, 1974).

6. Present at least one rational set of properly matched examples and nonexamples of varying difficulty level. A rational set of examples and nonexamples as defined by Markle and Tiemann (1969) is a set that includes as many nonexamples as there are defining attributes of the concept (each nonexample should have one defining attribute) and as many examples as there are variable attributes (each example should have one variable attribute). A sufficient number of sets should be included so that students learn the concept to the level desired.

In presenting each rational set, each example should be matched with a nonexample having the same variable attribute or attributes. The difficulty level within a set should range from easy to difficult but be appropriate to the target population of students. The use of rational sets effectively reduces and eventually eliminates errors of undergener-

alization, overgeneralization, and misconception (Feldman, 1972; Markle & Tiemann, 1969; Merrill & Tennyson, 1971; Swanson, 1972; Tennyson, 1973; Tennyson, Woolley, & Merrill, 1972). It is noted that matching examples and nonexamples on difficulty and also on both variable and defining attributes cannot be dealt with as precisely with all concepts as those reported in the preceding experiments.

7. Provide for feedback concerning the correctness and incorrectness of the responses. Clark (1971), Frayer and Klausmeier (1971), Markle (1975), and Sweet (1966) report the desirable effects of feedback to students. Clark (1971), for example, reported that concept attainment improved as the frequency of feedback increased up to 100 percent. Frayer and Klausmeier (1971) reported from their survey of research that feedback should be provided after every response, but that it is more important after an incorrect response. Feedback which tells the students not only that a response or hypothesis is wrong but which also enables them to infer how it is wrong and how to correct it is particularly helpful.

INSTRUCTIONAL PROGRAMMING FOR THE INDIVIDUAL STUDENT

The present study is investigating differentiation of instruction within the framework of the instructional programming model for the individual student (IPM). The IPM (Klausmeier, 1975) is a design for adapting instruction to the needs of the individual student and is intended for use by teachers in planning, implementing, and evaluating the instructional programs of individual students. It was also designed for use by textbook writers and curriculum developers.

The IPM is depicted in Figure 1. As can be seen, it consists of seven steps: (1) educational objectives are specified for the student population of a building; (2) the range of objectives that may be attainable for subgroups of the student population are determined; (3) an assessment is made of each child's level of achievement, learning style, and motivational level; (4) instructional objectives are set for each child for a specified period of time; (5) an instructional program suitable for each student is planned and implemented; and (6) assessment is made for attainment of objectives.

After Step 6, one of two procedures is followed, dependent on the mastery or nonmastery of objectives by each child. In case of mastery, the next sequence in the program is implemented or other actions are taken. If the objectives are not mastered, the student's characteristics are reassessed or other actions are taken (Klausmeier, 1975).

An important aspect of the IPM is that students ready to master the same set of objectives may be placed in a group for a specified period of time. At the end of each time period, postassessment and regrouping are done. In the elementary school, instruction dealing with closely related sets of objectives is called a unit of instruction. A unit of instruction is defined as a grouping of objectives and related instructional materials for which there is a beginning point and a terminal point (Klausmeier, 1975, p. 8). The science blocks used in the present study may be considered units of instruction.

Instruction in the IPM can be arranged so that students work independently, on a one-to-one basis with another student or the teacher, in

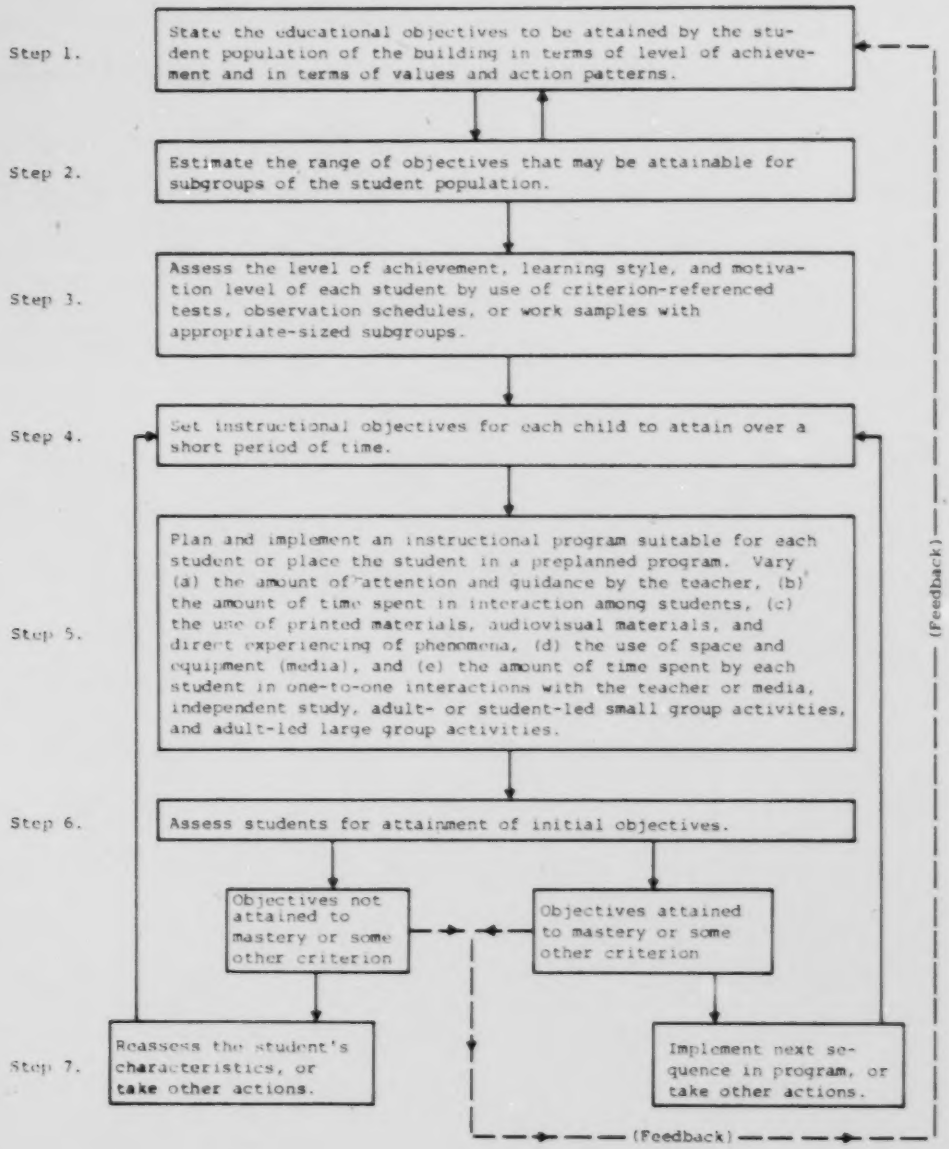

Step 1.
State the educational objectives to be attained by the student population of the building in terms of level of achievement and in terms of values and action patterns.
Step 2.
Estimate the range of objectives that may be attainable for subgroups of the student population.
Step 3.
Assess the level of achievement, learning style, and motivation level of each student by use of criterion-referenced tests, observation schedules, or work samples with appropriate-sized subgroups.
Step 4.
Set instructional objectives for each child to attain over a short period of time.
Step 5.
Plan and implement an instructional program suitable for each student or place the student in a preplanned program. Vary (a) the amount of attention and guidance by the teacher, (b) the amount of time spent in interaction among students, (c) the use of printed materials, audiovisual materials, and direct experiencing of phenomena, (d) the use of space and equipment (media), and (e) the amount of time spent by each student in one-to-one interactions with the teacher or media, independent study, adult- or student-led small group activities, and adult-led large group activities.
Step 6.
Assess students for attainment of initial objectives.
Objectives not attained to mastery or some other criterion
Objectives attained to mastery or some other criterion
Step 7.
Reassess the student's characteristics, or take other actions.
Implement next sequence in program, or take other actions.
(Feedback)
(Feedback)

Figure 1. Instructional Programming Model in IGE. (Adapted from Klausmeier, Quilling, Sorenson, Way, & Glasrud, 1971, p. 19.)

small groups, or in a combination of these modes. As children attain basic skills and the ability for self-direction, they may spend more time working independently or in small groups. Small groups may be either teacher-directed or teacher-monitored. Instructional materials, use of space, allocation of time, mode of instruction, type of instructional activity, and amount of teacher direction are all varied to meet the needs of each student.

COMPONENTS OF THE IPM IN THE PRESENT STUDY

A modified version of the model of instructional programming for the individual student (IPM) was used in the present study. The seven elements in the IPM as they were implemented in the study are examined below.

Step 1. Educational objectives were specified for the student population of a building. In the present study, the school-wide objectives for science were the objectives of the SAPA lessons specified for kindergarten through sixth grade.

Step 2. The range of objectives that may be attainable for subgroups of the student population were determined. In the school system in which the present study took place, 17 SAPA lessons were taught at each of two levels, five and six. Therefore, the range of objectives for science specified for the subgroups of the school population in the study (levels five and six) were objectives of the 17 SAPA lessons at each level.

Step 3. An assessment was made of each child's level of achievement, learning style, and motivational level. In the present study, each

child's level of achievement specific to the SAPA science lessons was assessed by a pretest at the beginning of each semester. The pretest determined each child's preinstructional knowledge relevant to the objectives for each SAPA lesson.

Step 4. Instructional objectives were set for each child for a specified period of time. In this study, the objectives of each SAPA science lesson were set for each participating child for the period of time during which the lesson was taught. The period of time depended upon the length and complexity of the lesson.

Step 5. An instructional program suitable for each student was planned and implemented. In this study, differentiation consisted of several components. First, children were grouped according to their pretest scores. This was done to facilitate planning and implementing instruction for each child.

In school E1 at level five, two methods of grouping were used. Two of the teachers at this level divided their children into higher and lower groups on the basis of pretest scores. One teacher taught the higher group and the other teacher instructed the lower group. The third teacher at level five in this school divided children into high, medium, and low groups within her intact classroom. At level six in school E1, the three teachers divided the children into high, medium, and low groups on the basis of their pretest scores. Each teacher taught one of the groups.

In school E2 at level five, the two teachers divided the children into two overlapping groups on the basis of pretest scores. These groups were

high-medium and medium-low. Each of the teachers instructed one of the groups. At level six in school E2, the children were placed into one of three groups on the basis of their pretest scores: high, medium, or low. Each of the three teachers at level six instructed one of these groups.

Once grouped, children received differentiated instruction according to their individual needs relevant to lesson objectives. Suggestions to teachers for differentiating instruction for the three groups are given in the Appendix.

Step 6. The attainment of objectives was assessed. This was done by administering a posttest to assess attainment of the SAPA lesson objectives immediately following completion of instruction in each SAPA lesson. Generally a child receiving a score of 80 percent or higher was considered to have achieved mastery. However, the criterion for mastery was set at 70 percent for some children in medium and low groups depending upon student ability, student effort, and lesson difficulty.

Step 7. The procedure followed after step six depended upon the mastery or nonmastery of instructional objectives. Where possible, reteaching was done with students who had not achieved mastery on the assessment of lesson objectives.

For level five at school E1, one teacher retaught 41 percent of all SAPA lessons taught during the year, a second teacher retaught 12 percent of the lessons, and the third teacher retaught 100 percent of the lessons. For level six at school E1, one teacher retaught 41 percent of the lessons, the second teacher retaught 53 percent of the lessons, and the third teacher retaught 18 percent of the lessons.

At school E2 for level five, one teacher retaught 24 percent of the SAPA lessons and the second teacher retaught 53 percent of the lessons. For level six at school E2, one teacher retaught 12 percent of the lessons, the second teacher retaught 12 percent of the lessons, and the third teacher retaught 41 percent of the lessons. Many of the teachers cited lack of time as the reason for not reteaching the SAPA lessons to children who had not achieved mastery of lesson objectives.

Reteaching was accomplished by additional instruction in the SAPA lesson by the teacher or a peer tutor, by the use of resource texts relevant to the SAPA lesson, or by other means determined by the teacher. During this phase, children who had achieved mastery read for enrichment in supplemental texts, worked on individual or group experiments or projects, or tutored other children who had not achieved mastery.

III

DEVELOPMENT OF PROCESS-CONCEPT ANALYSES

Before lessons are written to teach the various process-concepts of science, it is imperative that the concepts first be analyzed. In the published program, Science: A Process Approach (SAPA), there are eight "basic" processes (Observing, Classifying, Inferring, Predicting, Measuring, Using Numbers, Using Space/Time Relationships, and Communicating) and five "integrative" processes (Controlling Variables, Interpreting Data, Formulating Hypotheses, Defining Operationally, and Experimenting). An assumption which underlies the present study is that these science processes, as outlined in SAPA, may be taught as concepts. Described in this chapter is the specific procedure for conducting an analysis for each of the process-concepts.

Conducting a concept analysis includes (1) outlining the hierarchy or the taxonomy of which the target concept is a part, (2) stating a definition of the concept in terms of its defining attributes, (3) specifying the defining attributes and some of the variable attributes of the concept, (4) providing illustrative examples and nonexamples of the concept, (5) identifying some principles in which the concept is incorporated, (6) formulating problem-solving exercises involving use of the concept, and (7) developing a list of the key vocabulary associated with the concept. Procedures for carrying out steps (2), (3), and (4) are based on

the pioneering work of Markle and Tiemann (1969), while the other steps are related directly to the model of conceptual learning and development formulated by Klausmeier, Ghatala, and Frayer (1974).

Experience in developing concept analyses indicates that they have greatest utility in subsequently preparing instructional materials for any desired level of schooling when the analysis is directed toward the formal level of attaining the concept, and when the complete analysis is expressed in terminology appropriate for senior high school students rather than for young children. However, what is subsequently included in a particular set of instructional materials or methods must be related to the level of concept attainment to be taught and to the level of vocabulary and other characteristics of the target student population. A description of the procedures for conducting a concept analysis follows, using as examples of each procedure information pertaining to the concept observing scientifically. Each procedure is described in some detail because a concept analysis provides much of the information needed to develop instructional materials to teach the concept.

OUTLINING A HIERARCHY OR TAXONOMY

A starting point for the analysis of a concept is outlining the hierarchy or the taxonomy of which the concept is a part. Subject matter taught to children, kindergarten through high school, should be selected in the context of the structure of knowledge of the particular discipline or disciplines. This implies that the person conducting a concept analysis must know where a particular concept fits into a hierarchy or taxonomy,

how it is defined by experts in the discipline, how it is used in principles, and how it is used in solving various kinds of related problems.

A taxonomy involves inclusive-exclusive relationships among classes of things whereas a hierarchy implies relationships among things ordered by some principle, such as of importance, priority, and dependency. A learning hierarchy results from an analysis of a learning task. Three assumptions underlying this kind of analysis, and the concept of learning hierarchy, are: (1) learning tasks can be analyzed into skills, (2) all persons must learn the same prerequisite skills in order to perform a particular task, and (3) the same sequence of instruction will facilitate their learning.

The hierarchical organization as shown in Figure 2 for the basic and integrated science process-concepts results from an analysis of the inquiry skills in science that students should learn during their elementary school years, not from an analysis of the skills essential to conducting and reporting an experiment. However, the arrows do indicate dependency relationships of a non-inclusive type among concepts. For example, observing events is essential and prerequisite to drawing inferences about the events and also for classifying the events. In this kind of hierarchical organization of concepts, there may or may not be coordinate concepts at certain levels of the hierarchy.

In Figure 2 the dotted lines without arrows show a nondependency but not necessarily a coordinate relationship among the concepts. The defining attributes of the concepts and the inclusive-exclusive relationships in a hierarchical organization of concepts are very different from those

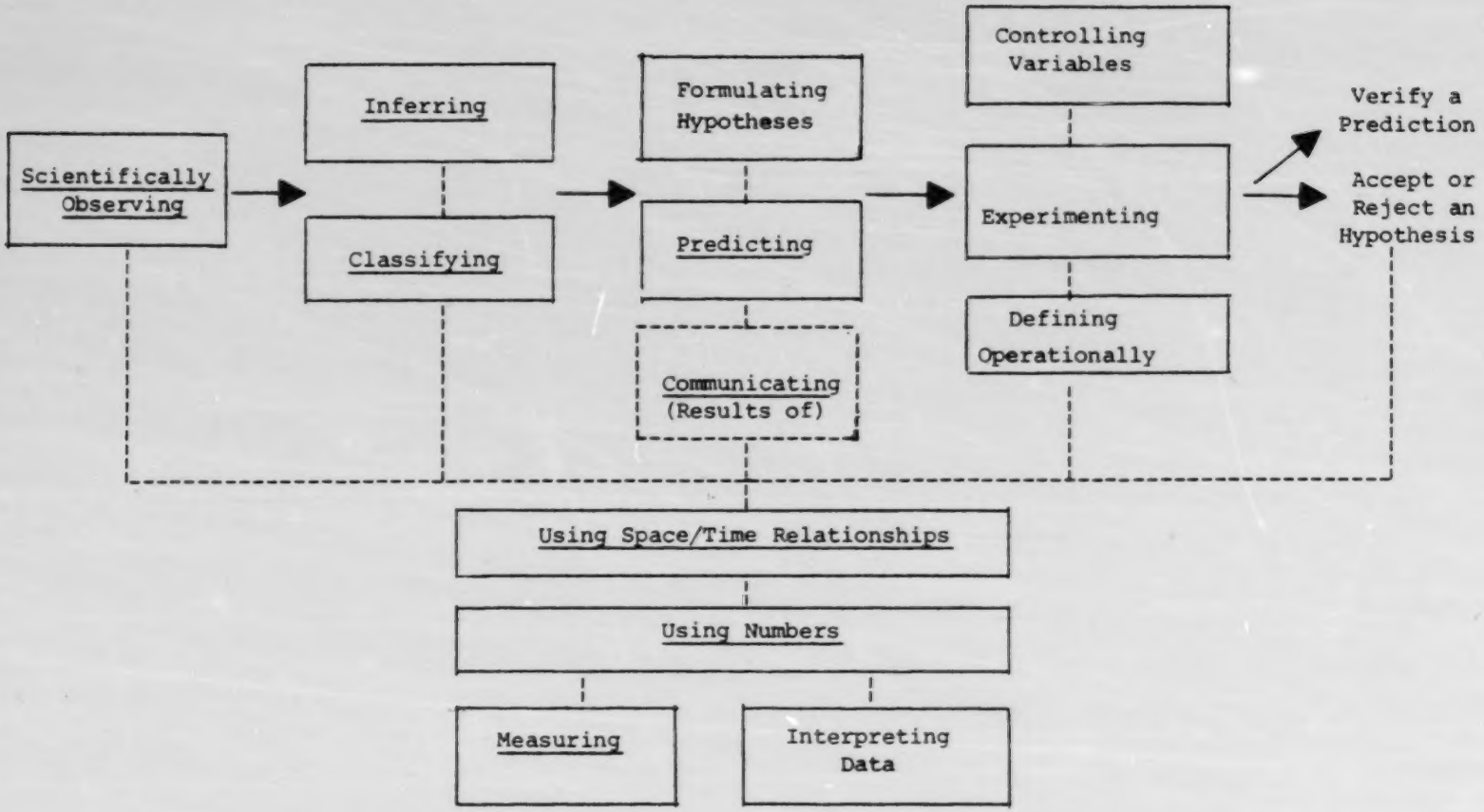


Figure 2. Relationships among the basic and integrated science process-concepts.

The process-concepts in this figure were drawn from Science: A Process Approach (AAAS Commission on Science Education, 1967); however, the figure itself is not.

in a taxonomy.

Bruner (1960) made a useful distinction between the structure of knowledge in a discipline and a structure of knowledge that is learnable by students. However, the latter cannot be derived without the former. Without knowledge of both kinds of structures, one cannot proceed intelligently in the analysis of concepts. At present much of the substance of school subject matters that could be organized into either taxonomies or hierarchies is not. In the absence of this kind of information, taxonomies and hierarchies are developed by using available printed materials and also by securing assistance from persons with expertise in the particular subject matter. The hierarchy presented in Figure 2 was formulated in this manner.

DEFINING THE CONCEPT

Whether or not students will be taught a definition of the word representing a particular concept, the person conducting an analysis must know or arrive at a societally accepted definition. Further, so that examples and nonexamples may be identified for use in teaching and testing, the meaning of the word should be stated in terms of the defining attributes of the concept represented by the word. For instance:

> Observing Scientifically -- Using one or more of the senses in critically examining objects or events and precisely recording data about those objects or events.

The reader will recognize that observing scientifically can be treated as a concept that can be understood, as a process or skill that

can be performed, or both. The authors treat it as both and presume that students' understanding it as a concept facilitates their learning to carry it out as a process.

Word definitions stated in terms of defining attributes cannot always be found in dictionaries. Definitions given in abridged dictionaries are usually synonyms, examples, or uses of the word in context. These also appear in unabridged dictionaries but are useless in determining the defining attributes (Markle, 1975). In arriving at the defining attributes of most concepts, the concept analyzer (if not expert in the particular subject matter) uses authoritative printed materials and also may seek the assistance of subject-matter experts.

SPECIFYING THE DEFINING ATTRIBUTES

The concept analyzer specifies the defining attributes of the concept in order to identify sets of teaching examples and nonexamples (Markle & Tiemann, 1969) and also to teach students an algorithmic strategy for evaluating instances as examples and nonexamples of the concept, as will be explained later.

Those attributes which are present in every example of a concept, and therefore also distinguish the concept examples from examples of all other concepts, are called the defining attributes of the concept. Establishing the defining attributes of the concept and arriving at a definition of the word representing the concept proceed simultaneously during a concept analysis.

The following rationale was adopted for determining the defining

attributes: the defining attributes of a process-concept are the more discrete operations that are used in performing the more global operation, and also the prerequisite prior operation(s). As can be seen in Figure 2, there are no processes designated as prerequisite to observing scientifically; therefore, the defining attributes of this process-concept are the more discrete operations which are involved, namely: (1) using one or more of the senses, (2) examining critically, and (3) recording data precisely.

SPECIFYING THE VARIABLE ATTRIBUTES

The variable attributes of the concept are identified to facilitate the later selection of examples and nonexamples. Examples of the same concept vary widely on their nondefining attributes. For example, reptiles are of many different colors and sizes; fish also vary in the same colors and are of various sizes. The attributes which members of the reptile class and members of the fish class have in common and which therefore may hinder persons in discriminating between the members of the two classes are called variable attributes. In most previous reports, starting with Bruner, Goodnow, and Austin (1956), these variable attributes have been called irrelevant attributes.

The first rule for identifying variable attributes is to identify those that are common to the concepts that are coordinate to the target concept. It is these attributes that are present in both the examples and nonexamples of a particular concept and that often lead to errors in classification. The second rule is to identify attributes that may be

present in both the target concept and either its supraordinate or subordinate concepts. With concepts that are not part of a taxonomy, one identifies the variable attributes intuitively, selecting those that learners may incorrectly consider as defining attributes of the target concept.

The rationale for specifying variable attributes was to select some of the more common attributes that vary among examples of the process, and to include attributes that are present in both examples and nonexamples of a particular process-concept. Often, the variable attributes of a particular process-concept are the same attributes which are variable for closely associated or coordinate process-concepts or include the attributes of any of the other operations with which the particular process might be easily confused.

Some of the variable attributes for observing scientifically are: (1) the objects or events being observed, (2) the sense or senses being used, (3) the place or situation in which objects or events are observed, and (4) the method of recording data.

SELECTING ILLUSTRATIVE EXAMPLES AND NONEXAMPLES

Examples and nonexamples of the concept are needed in teaching the concept and in assessing students' learning of the concept. At least one set of examples and nonexamples is identified during the concept analysis in such a way as to ensure that errors of undergeneralization, overgeneralization, and misconception by the learner will be avoided (Markle & Tiemann, 1969; Markle, 1975). When several concepts of the same taxonomy

are taught in a series of lessons, the nonexamples of any one concept are in reality examples of other concepts of the taxonomy. Using examples of related concepts for nonexamples of the target concept permits the defining attributes to be excluded meaningfully from each nonexample (thereby preventing overgeneralization) and the variable attributes to be included meaningfully in both the examples and nonexamples (thereby preventing undergeneralization).

One cannot deal with examples and nonexamples of concepts in a hierarchy as systematically as in a taxonomy, since there are often neither coordinate nor supraordinate concepts. An intuitive approach is required and the emphasis is placed more on the selection of examples and nonexamples than on matching the defining and the variable attributes. A few examples and nonexamples of observing scientifically follow:

(1) Example of observing scientifically (all defining attributes included and explicit): Bill looked at a marshmallow carefully, felt it, tasted it, and smelled it. Then he put it over the flame of a Bunsen burner and watched as it turned from white to black. He smelled it as it burned. After it cooled, he felt it and noticed that if felt crisp. He tasted it and thought that it tasted like charcoal. He recorded these things in his report book.

(2) Example of observing scientifically (all defining attributes included and explicit): Cindy asked Cecil to observe the liquid in two glasses scientifically. The liquid in both glasses was clear. Cecil's job was to decide if the same

liquid was in both glasses.

Cecil smelled the liquid in the two glasses, one at a time. First he smelled the liquid in Glass A. Then he smelled the liquid in Glass B. "No, Cindy," he said, "the liquid in the two glasses is not the same, even though they do look alike. The liquid in Glass B is alcohol. I can tell by the smell." Cecil wrote on the chart, "The liquids are different. Glass B is filled with alcohol."

(3) Example of observing scientifically (all defining attributes included and explicit): Cecil's assignment was to observe popcorn scientifically. He found a popcorn popper with a glass lid. He put in the oil, heated it, and then added the popcorn to pop. He watched carefully, writing down how long it took the corn to start popping. He listened to the sound it made and recorded the sound with his tape recorder. When it had stopped popping, he felt some with his fingers. It was smooth on the outside and crisp on the inside. He tasted it and noticed that it did not tast salty like the popcorn at the movie theater. He wrote all of this information accurately in his notebook so that he could write his report later.

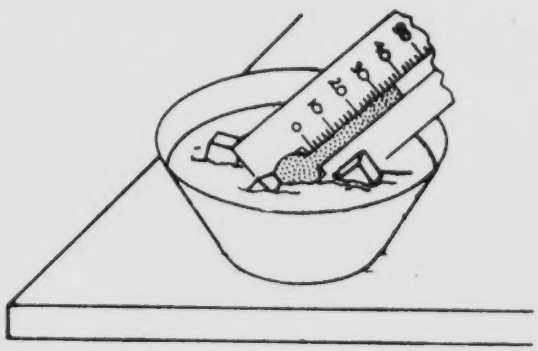
(4) Nonexample of observing scientifically (one or more defining attributes not included): Cecil saw the mailman deliver a box to the principal. Without looking at the label or inside the box, Cecil thought to himself, "The principal said he was going to order a new microscope for the school." Cecil saw

his friend, Jim, and told him that he saw the new microscope arrive.

(5) Nonexample of observing scientifically (one or more defining attributes not included): Cindy asked Cecil to observe the liquid in two glasses scientifically. The liquid in both glasses was clear. Cecil's job was to decide if the same liquid was in both glasses.

Cecil stood about five feet away from the two glasses. He quickly glanced at the liquids in the glasses. "Those glasses look like they are filled with the same liquid. They must both be filled with water." Cecil wrote on the chart, "The liquids in the two glasses are clear."

(6) Nonexample of observing scientifically (the defining attributes are actually those of another process-concept, namely measuring): Charlie wanted to find the temperature of the ice water in a bowl. He put a thermometer into the bowl of ice water. He looked carefully at the thermometer and said, "The temperature of the ice water is 36 degrees Fahrenheit."



IDENTIFYING ILLUSTRATIVE PRINCIPLES

One of the several ways in which concepts are useful to an individual is in understanding principles that incorporate the concepts. Understanding principles which involve cause-and-effect or correlational relationships among concepts, in turn, makes it possible to explain many events and, in some cases, to predict and to control (Bruner, 1960; Klausmeier, Ghatala, & Frayer, 1974). Understanding principles facilitates the solution of problems. It is useful, therefore, to identify illustrative principles of which the target concept is a part to promote transfer of concept learning to the understanding of principles.

The rationale for specifying principles was primarily as follows: (1) use relationships (cause-and-effect, correlational, probability, or axiomatic) between the target process-concept and other process-concepts in the proposed hierarchy (see Figure 2), (2) use relationships between the defining attributes related to the target process-concept, or (3) use relationships between the target process-concept and another related concept.

Illustrative principles involving the process-concept observing scientifically follow:

(1) Observing objects and events is prerequisite for drawing inferences regarding them.

(2) Using more than one of the senses in observing objects and events increases the probability of gaining more precise information.

(3) Quantitative observation permits the drawing of more precise inferences than does qualitative observation.

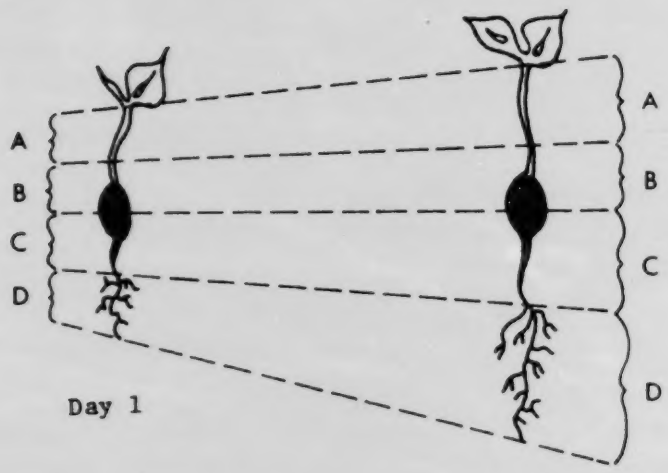
Examination of the principles indicates that each one expresses a relationship between the target concept and another one in the taxonomy or hierarchy, between the target concept and one or more of its defining attributes, or between the target concept and a less closely related concept. There appear to be no rules for arriving at a set of illustrative principles. However, once a principle is identified, correct applications and misapplications can be identified and used in teaching the principle (Feldman, 1974; Katz, 1975).

FORMULATING ILLUSTRATIVE PROBLEM-SOLVING EXERCISES

As part of a concept analysis, problem-solving exercises are formulated, the solutions of which presumably are facilitated by understanding the target concept and applying knowledge of a principle or a combination of principles. No attempt is made to make the problem-solving exercises of equal difficulty. On the contrary, a range of difficulty is preferable in the analysis so that additional examples of an appropriate level of difficulty can later be prepared for a particular target population of students.

A few problem-solving exercises for observing scientifically follow:

(1) The drawing below shows the growth of a plant over a 2-day period.



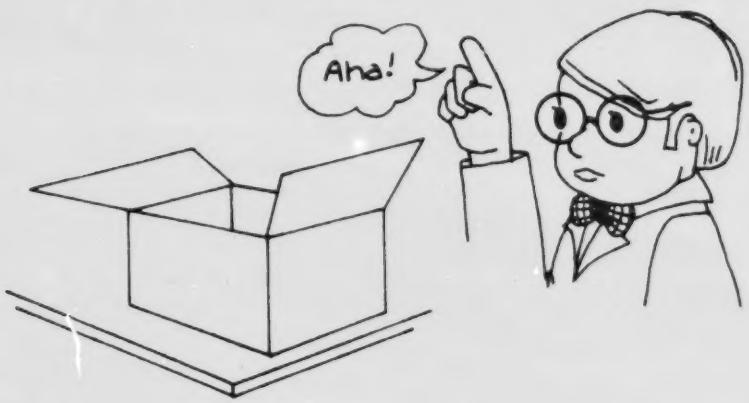
Which part has grown the most?

a. Part A
b. Part B
c. Part C
d. Part D

(2) What would you do to find out if some parts of a plant grow more quickly than other parts?

a. Weigh the plant now, and again at the end of 1 week.
b. Measure the height of the plant now, and again at the end of 1 week.
c. Count the number of leaves and roots which the plant has.
d. Put several marks on different plant parts, then place the plant beside a meter stick and observe daily.

(3) Cindy told Cecil to observe scientifically what was in a box in the next room. Cecil had never seen the box before. It had just come in the mail that day. Here are two endings to this story.



Ending 1

Cecil was in a hurry. He did not want to bother to go into the next room to look at the box and what was in it. "Hmm," he said to himself. "Cindy was going to order a new microscope." Without going to look at the box, Cecil wrote in his report book, "I have observed scientifically that there is a microscope inside the box."

Ending 2

Cecil went into the next room and looked at the large box on the table. He picked up the box, shook it, and listened to the rattling sound. Then he opened the box and felt inside carefully. He touched something that was metal and he felt its shape. It had the shape of a horseshoe. Then he looked inside and saw what he had felt. It looked like a magnet.

He took it out and tried it on some paper clips. He found that it was a magnet. He measured it and then wrote in his report book, "I have scientifically observed the object inside the box. It is a magnet. It is gray metal with red ends and is five inches high and three inches wide."

In which ending did Cecil observe scientifically?

a. Ending 1
b. Ending 2

DEVELOPING A VOCABULARY LIST

The rule for generating a vocabulary list as part of a concept analysis is to include the name of the concept and the key terms of the defining attributes. The extent to which the terms will be used in teaching a particular concept varies greatly according to the level of attainment desired. None of it may be used at the concrete level; all of it must be used at the formal level. Students' knowing the name of the concept and the names of its defining attributes correlates positively and highly with the level of concept attainment and also the uses of concepts (Klausmeier, Sipple, & Allen, 1974a, 1974b).

The vocabulary list for observing scientifically follows:

to observe (observing)

to record

to measure

to examin

senses

scientist

observer

information

experiment

accurately

precisely

critically

scientifically

SUMMARY

Conducting a concept analysis is necessary for preparing instructional materials to teach concepts, and is prerequisite to the writing of lessons and tests. The following steps are involved in the concept analysis procedure: (1) outlining the hierarchy or the taxonomy of which the target concept is a part, (2) stating a definition of the concept in terms of its defining attributes, (3) specifying the defining attributes and some of the variable attributes of the concept, (4) providing illustrative examples and nonexamples of the concept, (5) identifying some principles in which the concept is incorporated, (6) formulating problem-solving exercises involving use of the concept, and (7) developing a list of the key vocabulary associated with the concept.

IV

DEVELOPMENT OF PROCESS-CONCEPT LESSONS

The concept analyses explained in Chapter 3 formed the basis for the development of the process-concept lessons being used in the present study. Each of the lessons was developed by the Project staff and modeled after prior lessons on equilateral triangle (McMurray, Bernard, & Klausmeier, 1975) and tree (Klausmeier, Schilling, & Feldman, 1976). The effects of these prior lessons were noted earlier in Chapter 2.

While an optimal sequence of presenting items in the lesson has not been established empirically, the following sequence of elements based on rational analysis was used: (1) provide an interesting introduction; (2) present the key vocabulary; (3) teach the defining attributes of the concept; (4) teach the definition of the concept; (5) provide rational sets of examples and nonexamples of the concept; (6) teach a strategy for evaluating examples and nonexamples of the concept, in which the learner must evaluate examples and nonexamples; and (7) provide questions in each part (3) through (6) above with answers given immediately following, thereby providing feedback to the student.

As a means of focusing and holding student attention, a story format with characters is used in each lesson to present the information and instructions. The characters are represented in line drawings. Also, many of the examples and nonexamples are presented in drawings rather than in verbal statements. Each of the seven elements above was

incorporated in the process-concept lessons. The lessons developed for use in the present study at level five include: classifying (Schilling & Klausmeier, 1975), inferring (Schilling & Klausmeier, 1975), predicting (Swanson & Klausmeier, 1975), using numbers scientifically (Bull & Klausmeier, 1976), and measuring scientifically (Swanson, Schilling, & Klausmeier, 1976). At level six the lessons are: observing scientifically (Schilling & Klausmeier, 1975), inferring (Schilling & Klausmeier, 1975), using space/time relationships (Sipple, Katz, & Klausmeier, 1975), controlling variables (Schilling & Klausmeier, 1976), and communicating scientific information (Bull & Klausmeier, 1976). The seven elements will be explained below and illustrated by examples from the process-concept lesson observing scientifically.

(1) Present the key vocabulary. Before beginning instruction in the process-concept lesson, vocabulary charts with the key words used in the lesson are presented to the children. The key vocabulary consists primarily of names of the defining attributes. Other unfamiliar words in the lesson may also be presented in the list of key vocabulary. In presenting the key vocabulary, the teacher repeats each word and has the children repeat it. In this way, the children are taught to recognize the important words that they will be reading in the lesson. The vocabulary list for the lesson observing scientifically is presented below.

VOCABULARY LIST FOR THE PROCESS-CONCEPT LESSON OBSERVING SCIENTIFICALLY

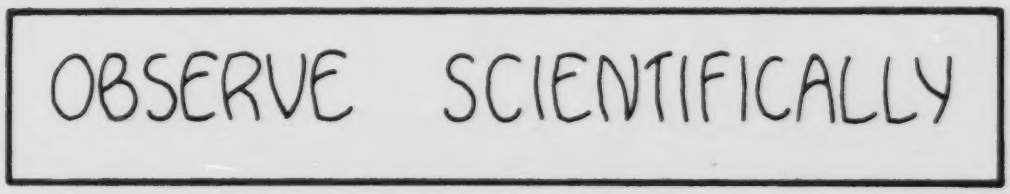
observing	record	instantly
scientifically	information	react
senses	accurately	definition
examine	stimulus	lizard
triangle	response	alcohol

(2) Provide an interesting introduction. At the beginning of each lesson, an introduction designed to establish an intention to learn the process-concept was presented. At this point, the story characters are introduced and the setting for the story is established. The introduction also explains that the purpose of the children in reading the lesson is to learn about the particular science process being taught. The introduction from the lesson observing scientifically is presented below.

AN EXAMPLE OF AN INTRODUCTION TO A PROCESS-CONCEPT LESSON
FROM THE LESSON OBSERVING SCIENTIFICALLY

Cecil is a scientist. Once upon a time Cecil was not a good scientific observer. He did not observe the way a scientist should observe. If something in a test tube fizzed, he didn't hear it. If something in his experiment changed color, he didn't see it. If something burned, he didn't smell it.

One day Cindy, another scientist, had a talk with Cecil. She said, "Cecil, scientists do many things. One of the most important things that they do is:



"By observing scientifically," said Cindy, "we learn information that will help us in our work. It is very important that we learn how to observe scientifically!"

In this lesson, Cindy is going to teach us to observe scientifically.

To OBSERVE SCIENTIFICALLY, we must:

1. Use one or more of our senses.
2. Examine something carefully.
3. Accurately record information about what is observed.

You and Cecil will learn about these three things by looking at pictures and reading about them. You will be asked to do things and to answer questions about what you are learning. After you answer the questions you will see the right answers. As you are reading this lesson, REMEMBER the three things that we do when we OBSERVE SCIENTIFICALLY.

(3) Teach the defining attributes of the concept. Following the introduction, each defining attribute of the process-concept is presented. The name of the defining attribute as well as the meaning of the attribute are explained and illustrated. The presentation of a defining attribute from the lesson observing scientifically is given below.

PRESENTATION OF A DEFINING ATTRIBUTE
FROM THE LESSON OBSERVING SCIENTIFICALLY

Cindy said:

To observe scientifically, a person must:

USE ONE OR MORE OF THE SENSES

The five senses we use in observing scientifically are:

hearing

seeing

smelling

touching

tasting

Sometimes we use all five senses in observing scientifically.

(4) Teach the definition of the concept. The concept analysis of each of the process-concepts included a technical definition of the concept. These technical definitions were revised to be appropriate for children in their fifth and sixth years of schooling. The revised definition for observing scientifically follows:

PRESENTATION OF DEFINITION FROM
LESSON ON OBSERVING SCIENTIFICALLY

When we put together the three important things about observing scientifically, we make the definition of observing scientifically.

Here is the definition of observing scientifically.

READ IT CAREFULLY.

OBSERVING SCIENTIFICALLY: Using one or more of the senses to examine something carefully and to accurately record information about what is observed.

(5) Provide rational sets of examples and nonexamples of the concept. Cartoons and short stories were used to present examples and nonexamples of the process-concepts. For each example, all of the defining attributes of the process-concepts were presented. For nonexamples one or more, but not all, of the defining attributes of the concept were present. Variable attributes of each concept were systematically varied across examples and defining attributes were excluded systematically from the nonexamples. Enough concept examples were presented to vary each major variable attribute across all examples, and enough nonexamples were presented so that each lacked one of the defining attributes. Part of a rational set of examples and nonexamples from the lesson observing scientifically follows:

(a) Example of observing scientifically (all defining attributes included and explicit):
Bill looked at a marshmallow carefully, felt it, tasted it, and smelled it. Then he put it over the flame of a Bunsen burner and watched as it turned from white to black. He smelled it as it burned. After it cooled, he felt it and noticed that it felt crisp. He tasted it and thought that it tasted like charcoal. He recorded these things in his report book.

(b) Example of observing scientifically (all defining attributes included and explicit);

Cindy asked Cecil to observe the liquid in two glasses scientifically. The liquid in both glasses was clear. Cecil's job was to decide if the same liquid was in both glasses. Cecil smelled the liquid in the two glasses, one at a time. First he smelled the liquid in Glass A. Then he smelled the liquid in Glass B. "No, Cindy," he said, "The liquid in the two glasses is not the same, even though they do look alike. The liquid in Glass B is alcohol. I can tell by the smell." Cecil wrote on the chart, "The liquids are different. Glass B is filled with alcohol."

(c) Example of observing scientifically (all defining attributes included and explicit):

Cecil's assignment was to observe popcorn scientifically. He found a popcorn popper with a glass lid. He put in the oil, heated it, and then added the popcorn to pop. He watched carefully, writing down how long it took the corn to start popping. He listened to the sound it made and recorded the sound with his tape recorder. When it had stopped popping, he felt some with his fingers. It was smooth on the outside and crisp on the inside. He tasted it and noticed that it did not taste salty like the popcorn at the movie theater. He wrote all of this information accurately in his notebook so that he could write his report later.

(d) Nonexample of observing scientifically (one or more defining attributes not included):

Cecil saw the mailman deliver a box to the principal. Without looking at the label or inside the box, Cecil thought to himself, "The principal said he was going to order a new microscope for the school." Cecil saw his friend, Jim, and told him that he saw the new microscope arrive.

(e) Nonexample of observing scientifically (one or more defining attributes not included):

Cindy asked Cecil to observe the liquid in two glasses scientifically. The liquid in both glasses was clear. Cecil's job was to decide if the same liquid was in both glasses. Cecil stood about five feet away from the two glasses. He quickly glanced at the liquids in the glasses. "Those glasses look like they are filled with the same liquid. They must both be filled with water." Cecil wrote on the chart, "The liquids in the two glasses are clear."

(f) Nonexample of observing scientifically (the defining attributes are actually those of another process-concept, namely measuring):

Charlie wanted to find the temperature of the ice water in a bowl. He put a thermometer into the bowl of ice water. He looked carefully at the thermometer and said, "The temperature of the ice water is 36 degrees Fahrenheit."

(6) Teach a strategy for evaluating examples and nonexamples of the concept. A strategy by which subjects could evaluate instances as examples or nonexamples was taught through the use of questions.

For each instance, the subject was given a set of questions concernint the presence or absence of the defining attributes. The subjects were told that if they could answer "yes" to all of the questions, the instance was an example of the concept. If they answered "no" to one or more of the questions, the instance was a nonexample. The strategy for evaluating an example and a nonexample of the process-concept observing scientifically is illustrated below.

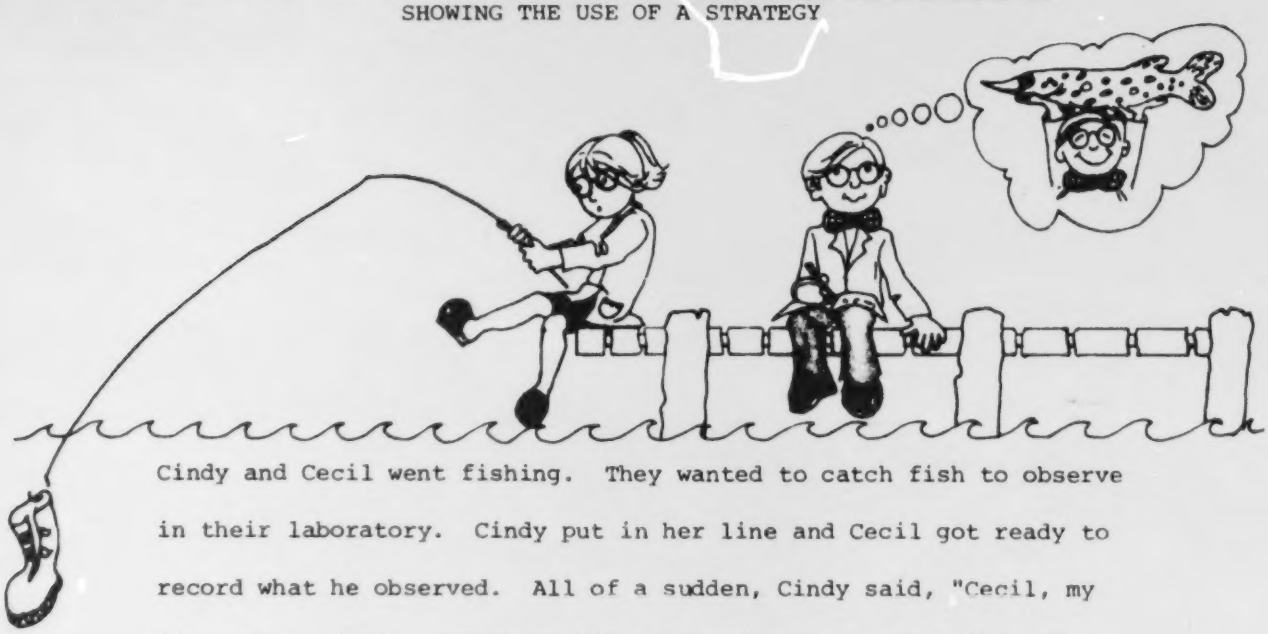
AN EXAMPLE OF THE PROCESS-CONCEPT OBSERVING SCIENTIFICALLY
SHOWING THE USE OF A STRATEGY

Cindy told Cecil to observe the ten-day-old plant again. This time Cecil looked at the plant carefully, felt its leaves, and measured it with a ruler. Then he wrote accurately in his report book, "The ten-day-old plant is three inches high. It has four leaves that are light green in color, smooth, and shiny. Its stem is very straight."

Did Cecil observe scientifically? Answer the three questions below.

1.	Did Cecil use one or more of the senses?	YES	NO
2.	Did Cecil examine something carefully?	YES	NO
3.	Did Cecil record information accurately about what was observed?	YES	NO
	(DID CECIL OBSERVE SCIENTIFICALLY?)	YES	NO

A NONEXAMPLE OF THE PROCESS-CONCEPT OBSERVING SCIENTIFICALLY
SHOWING THE USE OF A STRATEGY



Cindy and Cecil went fishing. They wanted to catch fish to observe in their laboratory. Cindy put in her line and Cecil got ready to record what he observed. All of a sudden, Cindy said, "Cecil, my line gave a jerk. Something big is on my line." Cecil did not see, hear, or feel anything. He only heard what Cindy said. He began to imagine what was on the line. "There are some big fish in this lake," he thought. "Cindy said something big was on her line. My uncle once caught a northern pike right here that was three feet long and weighed 15 pounds!" Cecil wrote in his report book: "I observed scientifically that the fish on Cindy's line is a northern pike, weighs 15 pounds, and is three feet long." Then Cecil ran off to tell his uncle about the fish. After he had gone, Cindy pulled in her line and there was a big boot filled with mud!

(continued on page 64)

Did Cecil observe scientifically? Answer the three questions below:

1. Did Cecil use one or more of the senses? YES NO

2. Did Cecil examine something carefully? YES NO

3. Did Cecil record information accurately about what was observed? YES NO

(DID CECIL OBSERVE SCIENTIFICALLY?) YES NO

(7) Provide the questions in each part (3) through (6) above with answers given immediately following, thereby providing feedback to the student. Questions in the process-concept lessons were of two types: (a) content-specific and (b) strategy-teaching. Content-specific questions dealt with information about the defining attributes of the process-concept which were presented in the first part of each lesson. Strategy-teaching questions accompanied rational sets of examples and nonexamples of the process-concepts. Correct answers were provided on the page following the questions. An illustration of the question and feedback technique from the lesson observing scientifically is given below.

AN EXAMPLE OF WITHIN-TEXT QUESTIONS AND IMMEDIATE FEEDBACK AS TO THE CORRECTNESS OF RESPONSES FROM THE LESSON OBSERVING SCIENTIFICALLY

THINK ABOUT IT!

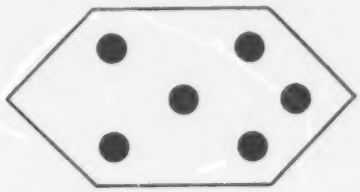
Answer each question by putting a circle around YES or NO.

1. We can record information only by writing it down. YES NO

2. We can record information only with a tape recorder. YES NO

3. Accurately means without making mistakes. YES NO

Examine the figure below. Your job is to accurately record information about the figure. Record the information by writing it on the lines after the questions.



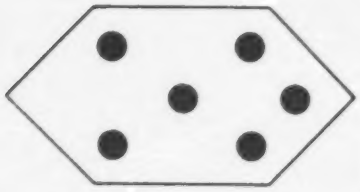
How many sides does the figure have? _____

How many balls are inside the figure? _____

PLEASE TURN THE PAGE AND LOOK AT THE ANSWERS.

ANSWERS

1. We can record information only by writing it down. YES (NO)
2. We can record information only with a tape recorder. YES (NO)
3. Accurately means without making mistakes. (YES) NO



How many sides does the figure have? 6

How many balls are inside the figure? 6

V

RESULTS OF SECOND-YEAR INTERVENTION AND PLANS FOR THIRD-YEAR INTERVENTION

During the 1975-76 school year, instruction in science at the two experimental schools, E1 and E2, was modified in two ways. First, process-concept lessons prepared by the Project staff were used as advance organizers at Levels 5 and 6 for certain designated sets of SAPA blocks of lessons. Second, students in the experimental schools were grouped for instruction in science with the groupings based on pretest scores.

One important condition of the experiment was that the amount of time given to the SAPA lessons would not be greater in the two experimental schools, E1 and E2, than in the paired control schools, C1 and C2. This constraint with respect to use of time permitted only a minimum amount of differentiation of instruction. The amount of differentiation was not sufficient to approximate that called for by the model of instructional programming for the individual student, i.e., the model developed by Klausmeier and others at the Wisconsin Research and Development Center for Cognitive Learning and used widely in IGE schools in reading and mathematics. Further, by adhering to the same sequence of 17 lessons in both the experimental and control schools as part of the experimental design, the additional use of the process-concept lessons increased the amount of information that the students dealt with during the same number of weeks of time. In essence, then, the experiment was conducted to ascertain the effects of the process-concept lessons and the modifications of instruc-

tion with the SAPA curriculum within time limits which were arranged so as not to increase the amount of time for instruction on the SAPA lessons. The dependent measures used in the study were SAPA tests, process-concept assessments, and an attitude inventory. The SAPA tests were developed by the Project staff to measure children's achievement of the specific objectives of the SAPA lessons as identified in the guides that accompany the SAPA materials. The process-concept assessments were developed by the Project staff to measure children's achievement of the particular process-concepts that the lessons purportedly are designed to teach. The attitude inventory was also developed by the Project staff to measure children's attitudes toward science. Results obtained related to each of these dependent measures follow.

RESULTS OF SAPA TESTS

During the 1975-76 school year SAPA tests were administered in the experimental schools at the end of each SAPA lesson; they were also combined and administered at the beginning and at the end of each semester for the lessons taught during the semester in both the experimental and control schools.

Table 8 presents a summary of the tests of significance run between the mean scores of the combined experimental schools and the combined control schools and also between the two pairs of schools. Analysis of covariance was used to determine statistical significance. The pretest score was used as the covariate.

At Level 5 in each semester and for the combined semesters, the children of the combined experimental schools achieved significantly

TABLE 8

SUMMARY OF TESTS OF SIGNIFICANCE FOR LEVEL 5 AND LEVEL 6: SAPA

		E1 and E2 with C1 and C2	E1 with C1	E2 with C2
Level 5	1st semester	.07	NS (.64)	.007
	2nd semester	.001	NS (.54)	.001
	1st and 2nd semesters combined	.007	NS (.48)	.001
	Tests B, C: Classifying	NS (.24)	NS (.57)	NS (.33)
	Tests D, E, F: Inferring	NS (.12)	NS (.86)	NS (.29)
	Tests G, H: Predicting	.003	NS (.23)	.001
	Tests I, J: Using Numbers	.001	.02	.01
	Tests K, L, M, N, O: Measuring	.001	NS (.54)	.001
Level 6	1st semester	.001	.001	.001
	2nd semester	.001	NS (.36)	.001
	1st and 2nd semesters combined	.001	.008	.001
	Tests B, C, D: Observing	.001	.008	.001
	Tests E, F, G: Inferring	.001	.04	.001
	Tests H, I: Using Space/Time	.001	.009	.001
	Tests J, K: Controlling Variables	.04	NS (.22)	.001
	Tests P, Q: Communicating	.001	NS (.27)	.001

Level 5

E1, N = 58
E2, N = 59
C1, N = 48
C2, N = 51

Level 6

E1, N = 60
E2, N = 70
C1, N = 45
C2, N = 55

higher on the SAPA tests than those of the combined control schools. As also shown in Table 8, the mean scores of the combined experimental schools were significantly higher than the combined control schools on three of the five process blocks at Level 5.

Table 8 shows that the students in the combined experimental schools at Level 6 scored significantly higher on the SAPA tests in each semester and for the semesters combined than did the students in the combined control schools. Also, the mean scores of the two experimental schools combined were significantly higher than the two control schools combined for each of the five process blocks at Level 6.

As may be observed in Table 8, the differences between the pairs of schools were generally significant except at Level 5 where the differences generally were not significant between Schools E1 and C1. The most consistent difference was between E2 and C2 at Level 6.

Table 9 gives the adjusted mean scores for the two pairs of schools. Although the adjusted posttest scores for E1 in comparison with C1 at Level 5 were very close in most cases, E1 had a substantial actual gain from pretest to posttest.

Table 10 gives the mean SAPA pretest scores, the mean posttest scores, and the mean gains for students at Levels 5 and 6 in each of the experimental and each of the control schools. These mean scores are not adjusted by analysis of covariance.

The mean gain scores for the Level 5 students in E1 were about the same as those for Level 5 of C1 for each semester and for the two semesters combined. For the combined semesters, E1 had a gain of 29.43, and

TABLE 9

ADJUSTED MEAN POSTTEST SCORES
FOR LEVEL 5 AND LEVEL 6 BY SCHOOL,
BY SEMESTER, AND BY BLOCK: SAPA

		E1	C1	E2	C2
Level 5	1st semester	54.14	54.93	58.79	55.28
	2nd semester	59.49	58.56	64.57	57.82
	1st and 2nd semesters combined	112.75	114.56	123.34	113.12
	Tests B, C: Classifying	13.03	12.67	13.08	12.65
	Tests D, E, F: Inferring	19.84	19.70	21.45	20.58
	Tests G, H: Predicting	15.03	14.22	16.61	15.00
	Tests I, J: Using Numbers	11.77	10.35	12.00	10.65
	Tests K, L, M, N, O: Measuring	32.79	32.15	36.03	31.91
Level 6	1st semester	61.93	56.52	67.64	58.74
	2nd semester	52.35	50.80	59.52	53.17
	1st and 2nd semesters combined	114.12	107.53	126.74	112.45
	Tests B, C, D: Observing	22.14	20.17	23.96	21.59
	Tests E, F, G: Inferring	19.96	18.25	21.21	17.97
	Tests H, I: Using Space/Time	12.52	11.09	15.72	11.00
	Tests J, K: Controlling Variables	13.45	14.20	15.90	13.63
	Tests P, Q: Communicating	12.89	12.19	15.65	12.31

TABLE 10

MEAN PRETEST, POSTTEST, AND GAIN SCORES FOR LEVEL 5 AND LEVEL 6 BY SCHOOL, BY SEMESTER, AND BY BLOCK: SAPA

		E1			C1			E2			C2		
		Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
LEVEL 5	1st semester	44.74	58.78	14.04	33.50	49.33	15.83	41.02	58.83	17.81	40.90	55.24	14.34
	2nd semester	47.90	63.29	15.39	39.25	53.96	14.71	42.37	63.80	21.43	43.98	58.71	14.73
	1st and 2nd semesters combined	92.64	122.07	29.43	72.75	103.29	30.54	83.39	122.63	39.24	84.88	113.94	29.06
	Tests B, C: Classifying	10.31	13.60	3.29	8.31	11.98	3.67	10.03	13.27	3.24	8.98	12.43	3.45
	Tests D, E, F: Inferring	16.17	21.24	5.07	12.06	18.00	5.94	14.14	21.32	7.18	14.78	20.73	5.95
	Tests G, H: Predicting	11.93	16.00	4.07	7.58	13.04	5.46	11.00	16.53	5.53	11.29	15.10	3.81
	Tests I, J: Using Numbers	9.71	12.05	3.34	7.75	10.00	2.25	7.66	11.64	3.98	8.63	11.06	2.43
	Tests K, L, M, N, O: Measuring	26.55	35.26	8.71	20.92	29.17	8.25	23.42	35.65	12.43	23.84	32.12	8.28
LEVEL 6	1st semester	43.97	62.48	18.51	42.56	55.78	13.22	45.91	68.78	22.87	43.23	57.31	14.09
	2nd semester	39.32	52.65	13.33	38.53	50.40	11.87	43.60	61.47	17.87	39.00	50.69	11.69
	1st and 2nd semesters combined	83.29	115.13	31.85	81.09	106.18	25.09	89.51	130.25	40.72	82.22	108.00	25.78
	Tests B, C, D: Observing	16.20	22.53	6.33	14.40	19.64	4.84	16.19	23.96	7.77	15.04	21.16	6.12
	Tests E, F, I: Inferring	13.47	19.40	6.41	11.71	16.33	4.62	14.57	21.44	6.87	13.67	17.67	4.00
	Tests H, I: Using Space/Time	9.13	12.53	3.40	9.02	11.07	2.05	9.39	15.66	6.27	9.69	11.07	1.38
	Tests J, K: Controlling Variables	10.17	13.45	3.28	10.16	14.20	4.04	11.03	15.97	4.94	10.75	13.55	2.80
	Tests P, Q: Communicating	9.75	12.77	3.02	10.16	12.36	2.20	10.81	16.31	5.50	9.51	11.84	2.33

C1 had a gain of 30.54. This finding will be discussed later. The mean gain scores for the Level 5 students in E2 were higher than those for C2 for each semester and also for the combined semesters, 39.24 in comparison with 29.06. In both pairs of schools, there were variations in the comparative amounts of gain for the different blocks of lessons. In general, E1 was slightly lower than C1 on three of the five blocks, and E2 was higher than C2 on four of the five blocks.

The mean gain scores for the Level 6 students in E1 were higher than those for C1 both semesters. Level 6, E1 students had higher gains than C1 on four of five blocks. The mean gain scores for Level 6 students in E2 were higher than those for C2 for both semesters. Similarly, the gains were higher for the Level 6, E2 group for all five SAPA blocks.

Table 10 shows that the experimental group most different from its control on the pretest was E1, Level 5. The mean pretest score of E1 was 11.24 higher than C1 for the first semester and 8.65 for the second semester. All other pairs for both semesters were much more alike in their mean pretest scores. This high pretest score is reflected in the relatively low gain score for E1, Level 5 of 14.04 and 15.39 for the first and second semesters in comparison with gains of 15.83 and 14.71 for C1 for the two semesters. Thus, although the students in E1, Level 5, did not gain more than those in C1, their actual posttest mean scores were comparatively high, 58.78 versus 49.33 first semester and 63.29 versus 53.96 second semester. It is possible that the substantially higher pretest scores for the Level 5 students in E1 made it difficult for them to show a large gain. Further, the much higher pretest score was totally

unexpected, making risky any comparisons of two supposedly similar child populations of the two paired schools.

Table 11 shows the scores on the SAPA tests given at the end of each lesson for Level 5 and Level 6 in each experimental school. In E1 at both Level 5 and Level 6, the posttest scores are lower on each block of lessons than were the scores on the same tests administered at the end of the block. At each level one or two mean scores show a substantial drop from the end of the lesson to the end of the semester. In E2 at Level 5, the loss was not as large on most of the lessons and in one set of lessons dealing with Predicting, the posttest score was actually higher.

TABLE 11

MEAN SCORES ON TESTS GIVEN AT THE END OF EACH LESSON FOR LEVEL 5 AND LEVEL 6 FOR EACH EXPERIMENTAL SCHOOL BY BLOCK: SAPA

		E1	E2
Level 5	Tests B, C,: Classifying	13.75	14.37
	Tests D, E, F: Inferring	21.31	21.39
	Tests G, H: Predicting	16.81	15.63
	Tests I, J: Using Numbers	14.21	11.68
	Tests K, L, M, N, O: Measuring	37.96	35.98
Level 6	Tests B, C, D: Observing	24.88	23.70
	Tests, E, F, G: Inferring	20.97	21.89
	Tests H, I: Using Space/Time	15.27	14.48
	Tests J, K: Controlling Variables	14.78	16.21
	Tests P, Q: Communicating	13.92	15.81

In E2 at Level 6 the posttest scores were slightly higher than the test scores given at the end of the lessons for three of the five blocks. It is presumed that the students in E2 learned the material more fully initially or subsequent process blocks were related to prior ones in such way that there was somewhat less loss.

RESULTS OF THE PROCESS-CONCEPT ASSESSMENTS

A process-concept lesson was used in the experimental schools with each SAPA block of lessons. A related assessment was administered to the students in both the experimental and control schools. A cumulative assessment was administered at the end of each semester to students in both the experimental schools and the control schools.

Table 12 presents a summary of the tests of significance for the

TABLE 12

SUMMARY OF TESTS OF SIGNIFICANCE FOR LEVEL 5 AND LEVEL 6: PCA

		E1 and E2 with C1 and C2	E1 with C1	E2 with C2
Level 5	Classifying	.01	.002	NS (.80)
	Inferring	.001	.001	.002
	Predicting	.001	.001	NS (.15)
	Using Numbers	.05	.001	NS (.11)
	Measuring	NS (.32)	NS (.74)	NS (.25)
Level 6	Observing	NS (.07)	NS (.61)	.001
	Inferring	NS (.32)	NS (.50)	.05
	Using Space/Time	.001	NS (.62)	.001
	Controlling Variables	.005	NS (.08)	.02
	Communicating	NS (.45)	NS (.73)	NS (.49)

process-concept assessments. These analyses are based on the assessments administered at the end of each semester.

The difference between the mean scores of the combined experimental schools and the combined control schools at Level 5 was significant for four of the five process-concept assessments; it was not significant for Measuring. The differences for the combined groups at Level 6 were significant for two of the five process assessments but not for the other three. As may be observed in Table 12, the differences between the mean scores were significant for four of the five process-concept assessments at Level 5, E1 and C1, and at Level 6, E2 and C2.

Table 13 gives the mean posttest scores of the children at the two

TABLE 13

MEAN POSTTEST SCORES FOR LEVEL 5 AND LEVEL 6: PCA

		E1	C1	E2	C2
Level 5	Classifying	13.98	12.04	13.93	13.80
	Inferring	9.62	7.98	9.69	8.27
	Predicting	9.38	7.50	9.42	8.80
	Using Numbers	7.24	5.65	5.71	6.18
	Measuring	6.00	6.10	5.80	6.10
Level 6	Observing	12.52	12.84	14.01	12.36
	Inferring	8.20	8.53	9.39	8.47
	Using Space/Time	12.47	12.18	13.76	11.45
	Controlling Variables	8.45	7.82	8.41	7.80
	Communicating	4.53	4.64	4.64	4.84

levels in the pairs of schools for the process-concept assessments. Level 5 students in E1 scored higher than those in C1 except on the last one, Measuring. The Level 5 students in E2 scored higher than those in C2 on the first three process-concepts but not on the last two, Using Numbers and Measuring.

At Level 6, the students in E1 scored higher than those in C1 on two of the three process-concepts; while students at Level 6 in E2 scored higher than those in C2 on four of the five process-concepts. It is noteworthy, and this will be discussed later, that the E1 and E2 students consistently were lower than the C1 and C2 students on the last process-concept assessment administered late in the second semester. We shall notice next that students' attitudes toward science were lower in May than in either September or December.

RESULTS OF THE SCIENCE ATTITUDE INVENTORY

A Science Attitude Inventory was administered in September, 1975 to the experimental and control groups. It was administered again in December and May, 1976 at the end of each of the two semesters. The pretest score was used as the covariate in the analysis of covariance performed on the December and May scores.

Table 14 presents a summary of the tests of significance. At Level 5 the difference between the combined experimental and control groups was not significant in December, but it was in May, favoring the experimental groups. At Level 6 the difference was significant in December, but not in May; the difference favored the control groups in December. As may be observed in Table 14, the difference between E1 and C1 at Level 5

was significant in December and also in May. The only significant difference between E2 and C2 was in December at Level 6.

TABLE 14

SUMMARY OF TESTING OF SIGNIFICANCE
FOR LEVEL 5 AND LEVEL 6: SAI

		E1 and E2 with C1 and C2	E1 with C1	E2 with C2
Level 5	December	NS (.53)	.02	NS (.29)
	May	.02	.006	NS (.42)
Level 6	December	.004	NS (.13)	.02
	May	NS (.99)	NS (.59)	NS (.52)

Table 15 gives the mean SAI scores for all groups in September, December, and May. Means for Level 5 students in E1 were consistently higher than those for C1; while the means for E2 were higher in September and May but lower in December. It is interesting to note that only the Level 5 students in E1 and E2 had higher mean attitude scores in May than September. The means for the Level 6 students in E1 were higher than those for C1 in September but lower in December and May; while the means for E2 were lower than those for C2 in September and December, but slightly higher in May. All Level 6 groups, except the C1 group, had lower mean attitude scores in May than in September.

TABLE 15

MEAN SCORES FOR LEVEL 5 AND LEVEL 6: SAI

		E1	C1	E2	C2
Level 5	September	45.47	44.38	45.36	44.08
	December	49.60	45.65	46.29	47.90
	May	48.12	43.10	45.58	43.67
Level 6	September	44.67	42.16	44.30	44.65
	December	42.97	44.53	42.89	46.45
	May	43.00	43.29	41.17	40.18

DISCUSSION OF 1975-76 RESULTS

Despite the substantial constraints put upon the experiment in terms of time, the results are noteworthy, and all of the significant differences except one dealing with attitudes favored the experimental schools. The research team and personnel of the experimental schools anticipated a few more significant differences favoring the experimental schools. Three main unanticipated conditions may be related to the lack of more and larger differences.

First, the Level 5 students in E1 scored very much higher than expected on the SAPA pretests. This is possibly why they did not gain as much or more than the paired control group. We note that the Level 5, E1 group also scored relatively high on the science attitude inventory throughout the year.

Second, we believe that the massive amount of information in the

process-concept lessons, along with not giving more time than the control schools to the SAPA lessons, resulted in a situation whereby some students in the experimental schools did not learn the substance in either set of materials well.

Third, much SAPA, PCA, and SAI testing occurred late during the second semester of the school year, and a Ph.D. study (Schilling, 1976) was also carried out betwe n blocks of process-concept lessons late during the school year. The Ph.D. study involved some students doing another process-concept lesson and some received much additional testing. The additional amount of information and time required of the students and teachers in connection with the Ph.D. study probably had a negative effect on the performances of the students, particularly on those in the experimental schools since they had already received five process-concept lessons during the year. It is possible, too, that the considerable amount of testing done late in the school year adversely affected the science attitudes of all the students in all the schools.

PLANS FOR FIRST SEMESTER 1976-77 INTERVENTION

Although significant and positive results were obtained with the intervention procedures used during 1975-76, the actual modifications in the instructional process were relatively minor and the time constraint did not permit near-mastery students to move to mastery under additional instruction. During 1976-77 the intervention procedures will be more clearly defined in order to carry out instructional programming for the individual student more fully and without a time constraint. It will

also be important to determine the effect of a process-concept lesson when not given in conjunction with differentiation of instruction. During the first semester of the 1976-77 school year, the study will be focused upon two major intervention procedures: (1) the effect of a process-concept lesson, and (2) the effect of more clearly defined instructional programming for the individual student. It is possible that with sufficient time to carry out recommended procedures there will be more consistent positive results and even larger differences between experimental and control conditions than were obtained during 1975-76.

The Process-Concept Lesson

In order to determine the effect of presenting a process-concept lesson separately from differentiation of instruction, the observing scientifically lesson, unmodified in content, will be given to the Level 6 children in the two experimental schools before regular instruction on the first block of SAPA lessons. The process-concept lesson and three SAPA Observing lessons will be taught from mid-September through mid-October, 1976. Two dependent measures will be used to assess understanding of the process-concept lesson. An 18-item multiple choice test identical to the process-concept assessment for observing scientifically used during 1975-76 will be given as well as a newly developed 10-item multiple choice test. The 10-item test differs in that the content of the questions corresponds to the content of the SAPA lessons taught during this block of instruction. In particular, the items will deal with the process observing scientifically as applied to magnets and magnetic poles, the growth of plants from seeds, and falling objects. Although

Level 6 children in the two control schools will not receive the observing scientifically process-concept lesson, they will be given the 18-item and the 10-item assessments. A further control will consist of comparing performance of Level 6 children during 1975-76 with performance of Level 6 children during 1976-77.

Approximately 120 minutes will be spent in each experimental school on the process-concept lesson prior to instruction on the three SAPA Observing lessons. It is expected that Parts A, B, and C of the process-concept lesson will be read by the teacher and students together, with the teacher leading discussion and occasionally supplementing points raised in the lesson with informal instruction. Part D of the observing scientifically lesson will be read silently by the students. If time permits following the assessment, those students who were not at mastery level may receive additional instruction on the process-concept lesson.

Differentiation of Instruction

During the first semester of the 1976-77 school year, complete differentiation of instruction will be carried out only with the block of SAPA Inferring lessons to be taught from mid-October through late November. No process-concept lesson on inferring will be presented in order to ensure adequate time for differentiation procedures to be carried out and in order to evaluate the effects of instructional programming for the individual student in the absence of a process-concept lesson. It is possible that in 1976-77 with a greater amount of time given to instruction and a more appropriate use of activities, materials, and groupings, the experimental students will score consistently higher on the SAPA

tests than control students than was the case in 1975-76.

Three groups in each experimental school for differentiated instruction will be formed prior to instruction on SAPA lessons in the Inferring block. The high (middle, low) group at each school will be composed of the students whose total scores on a series of SAPA Inferring tests are in the upper (middle, lower) one-third of the fifth grade of the school. Each of these homogeneous groups will include from 25 to 30 students. For students who participate in the study during 1975-76, six Inferring test scores will be used in determining the groups: three Level 5 posttest scores from the May, 1976 administration and scores on the three Level 6, September, 1976 pretests.

Instruction for the Inferring block of lessons will be approximately six weeks in length. The sequence of instruction in experimental schools for the first lesson in the block, Inferring 6, will proceed as follows:

(a) All students (high, middle, and low groups) will receive approximately 180 minutes of SAPA instruction on all of the activities associated with the lesson on loss of water from plants.

(b) A ten-item posttest covering the content of the Inferring 6 lesson will be administered and scored immediately by an instructional aide who works in the school.

(c) Based on the rank order configuration of scores obtained for the posttest, three new groups of equivalent size will be formed for the purpose of re-teaching and/or enrichment. For instance, roughly one-third of the students may attain a post-

test score of 8, 9, or 10; another one-third may achieve a score of either 6 or 7; and the remainder of the students may score in the 0 through 5 range.

(d) Students will move into new classroom size groups on the basis of their posttest scores, and will review the posttest during the first 15 to 30 minutes. For the remaining 60 to 75 minutes of instruction on Inferring 6, the students will pursue activities that are appropriate to the level of mastery attained. High scoring students will receive some re-teaching of the lesson and proceed to related enrichment activities; students scoring in the middle range will primarily receive re-teaching on the Inferring 6 content; low-scoring students will receive additional instruction on the Inferring 6 lesson with possible supplementary activities either in the instructional materials center and/or with classmate tutors.

This same instructional sequence will occur for the other two SAPA lessons in the Inferring block. Approximately 245 minutes of initial SAPA instruction and 120 minutes of re-teaching/enrichment are set aside for Inferring 7, a lesson on inferring connection patterns in electrical circuits. For the Inferring 8 lesson related to the shape of cut things, approximately 180 minutes of initial instruction and 90 minutes of re-teaching/enrichment are scheduled.

The two control schools will not group students on the basis of SAPA test scores, but will spend approximately the same number of minutes in science instruction as the experimental schools are scheduled to spend on

initial teaching of the content before re-grouping and re-teaching/enrichment. In other words, the control schools are expected to spend roughly 180 minutes on Inferring 6, 245 minutes on Inferring 7, and 180 minutes on Inferring 8.

PLANS FOR SECOND SEMESTER 1976-77 INTERVENTION

While intervention procedures during first semester 1976-77 are intended to determine the separate effects of process-concept lesson and differentiation of instruction, tentative plans for second semester involve combining the process-concept lesson and differentiation procedures for one process block of instruction. Specific instructional variations will depend upon analysis of the effectiveness of procedures used during first semester.

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APPENDIX

SUGGESTIONS TO TEACHERS FOR DIFFERENTIATING INSTRUCTION IN EACH EXPERIMENTAL SCHOOL

At the beginning of each block of SAPA lessons, the students should be grouped on the basis of SAPA pretest results and teacher judgment. For the purposes of differentiated instruction, it is suggested that three homogeneous groups be formed: the high group should include students whose pretest scores rank in the top one-third, the medium group should include students whose scores rank in the middle one-third, and the low group should include those students whose scores rank in the bottom one-third.

HIGH GROUP

In presenting SAPA lesson content to the students in this group, the teacher should limit the amount of time spent on large-group introduction and demonstration, and encourage small-group or independent study. Students who demonstrate mastery of the SAPA content (generally, by achieving a score of 80% or higher on the posttest) should receive enrichment activities, tutor other students, or work on individual projects. In planning for student enrichment in this group, include the media center, supplementary texts (resource file for Houghton-Mifflin, Follett, and Addison-Wesley science materials), science kits, community projects, reports, and demonstrations.

The teacher should provide additional SAPA content instruction for those students who do not attain mastery (at the 80% level), using supplementary texts as well as SAPA materials.

MEDIUM GROUP

For each SAPA lesson, the teacher should provide a thorough intro-

duction, teach important vocabulary words, give large-group demonstrations, and encourage study in small-groups as appropriate. The amount of time spent on the SAPA lesson should be somewhat greater for this group than for the high group. Depending upon student effort and lesson difficulty, the teacher may wish to choose a level of mastery in the 70% to 80% range for this group.

LOW GROUP

It is expected that the amount of time required to teach each SAPA lesson will be greatest for this group. Nearly all of the time allotted for a given lesson should be spent in large-group, teacher-led activities: introduction to the SAPA lesson, learning vocabulary, and doing experiments. After the SAPA posttest, rather than receiving SAPA lesson content, students may engage in additional reading from supplementary or lower level science texts depending upon mastery level attained on the posttest and/or individualized instruction with a tutor from the medium or high group.

Center Planning and Policy Committee

Richard A. Rossmiller
Wayne Otto
Center Co-directors

Wayne Otto
Area Chairperson
Studies in Reading, Language and Communication

Marvin J. Fruth
Area Chairperson
Studies of Implementation of Individualized Schooling

Herbert J. Klausmeier
Area Chairperson
Studies of Instructional Programming for the Individual Student

James M. Lipham
Area Chairperson
Studies of Administration and Organization for Instruction

Thomas A. Romberg
Area Chairperson
Studies in Mathematics and Evaluation of Practices in Individualized Schooling

Associated Faculty

Vernon L. Allen
Professor
Psychology

B. Dean Bowles
Professor
Educational Administration

Thomas P. Carpenter
Associate Professor
Curriculum and Instruction

W. Patrick Dickson
Assistant Professor
Child and Family Studies

Marvin J. Fruth
Professor
Educational Administration

John G. Harvey
Professor
Mathematics
Curriculum and Instruction

Frank H. Hooper
Professor
Child and Family Studies

Dale D. Johnson
Professor
Curriculum and Instruction

Herbert J. Klausmeier
V.A.C. Henmon Professor
Educational Psychology

Joseph T. Lawton
Assistant Professor
Child and Family Studies

Joel R. Levin
Professor
Educational Psychology

James M. Lipham
Professor
Educational Administration

Dominic W. Massaro
Professor
Psychology

Donald M. McIsaac
Professor
Educational Administration

Wayne R. Otto
Professor
Curriculum and Instruction

Penelope L. Peterson
Assistant Professor
Educational Psychology

Robert G. Petzold
Professor
Music
Curriculum and Instruction

Thomas S. Popkewitz
Associate Professor
Curriculum and Instruction

Gary G. Price
Assistant Professor
Curriculum and Instruction

Thomas A. Romberg
Professor
Curriculum and Instruction

Richard A. Rossmiller
Professor
Educational Administration

B. Robert Tabachnick
Professor
Curriculum and Instruction

J. Fred Weaver
Professor
Curriculum and Instruction

Gary G. Wehlage
Associate Professor
Curriculum and Instruction